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USING AUTOMATIC IDENTIFICATION TECHNOLOGIES FOR LOGISTIC SUPPORT ON BATTLEFIELDS OF THE FUTURE

by

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USING AUTOMATIC IDENTIFICATION TECHNOLOGIES FOR LOGISTIC SUPPORT ON BATTLEFIELDS OF THE FUTURE

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LIST OF ACRONYMS

AC/RC	Active Component/Reserve Component
AEI	Automatic Equipment Identification
AIT	Automatic Identification Technology
ALOC	Air Line-of-Communications
AMS	Automated Manifest System
ANSI	American National Standard for Information Exchange
ASLP	Army Strategic Logistics Plan
ATAV	Army Total Asset Visibility System
ATM	Automatic Teller Machine
CASCOM	Combined Arms Support Command
CINC	Commander-in-Chief
CONUS	Continental United States
DAMMS	Department of the Army Movement Management System
DDSP	Defense Distribution Depot Susquehanna Pennsylvania
DODAAC	Department of Defense Activity Address Code
DoD	Department of Defense
DoDLSP	Department of Defense Logistics Strategic Plan
DTTS	Defense Transportation Tracking System
ERF	European Redistribution Facility
FLOT	Forward Line of Own Troops
FM	Field Manual
HELP	Heavy Vehicle Electronic License Plate Project
HSDS	Hub and Spoke Distribution System
ITV	In-Transit Visibility
JLOTS	Joint Logistics Over-The-Shore
JTF	Joint Task Force

LIA	Logistics Integration Agency
LIF	Logistics Information File
LSE	Logistic Support Element
MB	Megabytes
MICR	Magnetic Ink Character Recognition
MCT	Mobile Communications Terminal
MCC	Movement Control Center
MMC	Materiel Management Center
NATO	North Atlantic Treaty Organization
NFESC	Naval Facilities Engineering Service Center
OCR	Optical Character Recognition
ODCSLOG	Office of the Deputy Chief of Staff for Logistics
OJE	Operation Joint Endeavor
OOTW	Operations Other Than War
OMFTS	Operational Maneuver From The Sea
OPCON	Operational Control
RF	Radio Frequency
RF ID	Radio Frequency Identification
SARS	Standard Army Retail Supply System
SLA	Strategic Logistics Agency
STAMIS	Standard Army Management Information System
TAV	Total Asset Visibility
TCMD	Transportation Control and Movement Document
TCN	Transportation Control Number
TRADOC	Training and Doctrine Command
ULLS	Unit Level Logistics System
USAMMC	United States Army Medical Materiel Center
USC	United States Code
USTRANSCOM	United States Transportation Command

USAREUR	United States Army Europe
WPS	Worldwide Port System

I. INTRODUCTION

A. OVERVIEW

As we prepare to enter the twenty-first century, Army leaders recognize we are entering a time of great strategic and technological change: The Army that operated so effectively in Desert Storm and other conflicts this century is not the same Army we will need to fight and win conflicts that may arise in decades to come. Drastic changes in "world order," coupled with rapid advances in technology, are necessitating corresponding changes in U.S. security strategy and the forces that implement that strategy. Consequently, Army leaders are reshaping the Army--from a forward-deployed force to a U.S.-based, rapid-deployment force --at the same time they are redefining potential adversaries and battlefields. These changes in turn are transforming the way Army forces will be *supported* in future conflicts. For example, it is likely that future conflicts will require the movement of more equipment and personnel than planned for in previous war plans, and there will be little time for correcting shipping errors or finding lost equipment.

A critical element of being able to support Army forces as they fight on future battlefields will be harnessing certain emerging technologies and exploiting their potential logistic uses. The family of technologies called Automatic Identification Technology (AIT) offers many potential logistic uses, from automatic manifesting of containers to locating trucks and critical supplies on the battlefield. AIT can play an essential role in systems that tell commanders where their limited assets are and that help ensure commanders get the right equipment where they need it and when they need it.

This thesis analyzes potential roles for automatic identification technologies for logistic support on future battlefields. In particular, the thesis will focus on applications related to supporting Army forces, within the context of the Army's vision of future battlefields and how units that operate on them will be supported.

B. RESEARCH OBJECTIVES

The main objective of this thesis is to answer the questions listed below.

1. Primary Questions

- What structural and doctrinal impacts will the emerging Force XXI concept have on future Army forces and how they are supported?
- What is the Army's vision of future battlefields and areas of operations?
- Given that environment, what roles can automatic identification technology play in supporting Army forces?

2. Secondary Questions

- What decisions have already been made with respect to Army uses of AIT?
- What are the results from recent or ongoing Army applications of AIT?

C. SCOPE AND LIMITATIONS

While potential (or current) applications for AIT exist for each of the military services, this thesis discusses only applications related to Army forces. It is further limited to support applications, as opposed to direct combat or operational applications. Most of the technology discussion focuses on Radio Frequency Identification, one of the most powerful automatic identification technologies. Six other technologies are discussed briefly, for comparison purposes and to provide the reader background.

A significant limitation for this thesis is the fact that AIT is an emerging technology: as with other "hot" technologies of today, advances in the field are made continuously, and observations made one month may be quickly outstripped by new hardware, software, or procedures developed the next month. Further, at the time of this writing, several AIT systems are undergoing extensive real-world testing in support of United States and NATO operations in Bosnia. While initial impressions of AIT effectiveness in that operation are available, comprehensive analysis of its effectiveness will not be available for many months beyond the date this thesis was completed.

D. METHODOLOGY

The primary method of gathering background material was extensive review of existing literature and on-line resources. Additional valuable insight was gained through interviews with knowledgeable individuals from both the Army logistics community and civilian industry. Among military interviewees were several current and past senior commanders of Army support units. Senior Department of Defense (DoD) civilians at key Army planning and support agencies also provided essential data and insight. Among civilian industry interviewees were engineering and marketing representatives from the two companies currently providing the lion's share of AIT to the Army and DoD: Savi Technology, Inc. and QUALCOMM, Inc.

E. THESIS ORGANIZATION

This thesis is divided into five chapters. The current chapter provides a thesis overview. Chapter II discusses the principal types of automatic identification technologies, with an emphasis on radio frequency identification. Chapter III discusses the dynamics shaping the "Army of the future," the characteristics of that Army, and the characteristics of the logistics system that will support it. Given those dynamics and characteristics, Chapter IV discusses potential roles for AIT in supporting the Army. Chapter V provides conclusions from the research.

II. AUTOMATIC IDENTIFICATION TECHNOLOGIES

A. INTRODUCTION

The rapid advance of technology in recent years has led to many technologies that initially appear bold and unusual, but soon become part of daily life--and in so doing, significantly transform aspects of our lives. Automatic Identification Technologies (AIT) are a notable example of this phenomenon. AIT includes many remarkable innovations that we now see or use daily, such as bar coding, optical character recognition (OCR), and magnetic stripe. These developments have so pervaded our society that we hardly notice their presence on groceries, checks, ATM cards, and so on. But noticed or not, these developments have had a tremendous positive impact on efficiency and accuracy of many processes that take place in our society.

AIT also includes other technologies that are not quite as pervasive, such as "smart" cards, voice recognition systems, and radio frequency identification systems. However, like the more prevalent examples mentioned above, these technologies also appear poised to dramatically alter the way many functions are performed in today's world. This chapter will discuss the principal types of automatic identification. It will discuss how each technology works, give examples of current applications, and consider some strengths and weaknesses of each. After brief discussions of the first six technologies (bar coding, OCR, magnetic stripe, smart cards, optical/laser cards, and voice recognition), a more thorough discussion of radio frequency identification technology will be presented.

B. BAR CODES

1. The Technology

Bar code symbols are the most pervasive of all Automatic Identification technologies: most Americans probably see or touch something with a bar code on it every day. Bar code symbols are composed of a series of thick or thin lines and spaces. Together, the lines and spaces represent alpha-numeric and control characters (Gold, 1988, p. 1-2). The characters in a bar code are read by an optical scanner, which contains a source of intense light (usually a laser or light-emitting diode) that is aimed at the pattern of lines and spaces; the dark bars absorb the light, and the white spaces between the bars reflect the light. The resulting pattern of light and dark is measured by a decoder in the scanner, then translated into a binary code and transmitted to a computer. (AIM-USA, 1992, p. BG2)

There are two broad categories of bar code scanners: contact and non-contact. The difference between the two types is self-evident. The most common contact scanner is the wand, which uses an internal LED sensor to read bar codes it is passed across. This type of scanner is typically the least expensive, and provides a high "performance to cost ratio" (Gold, 1988, p. 1-3).

Non-contact scanners are significantly more expensive, but provide greater throughput and flexibility. As their name suggests, these scanners can read bar codes without being placed in physical contact with the bar codes. Depending on the specific type of scanner, bar codes can be read from distances ranging from a few inches to a few feet. Non-contact scanners provide the opportunity to use automatic identification in an environment, such as certain manufacturing situations, in which it is "difficult, dangerous, or impossible to get close enough to touch the bar code label" (Gold, 1988, p. 1-3).

2. Strengths

Bar code technology offers several significant strengths, summarized below.

- Rapid data entry - Bar coded information can be entered at a rate of up to thirty characters per second, much faster than even a skilled typist.
- Use of unskilled labor for data entry - Minimal training is required to teach a person to operate a bar code scanner.
- Minimization of errors - Data from bar codes is essentially error free, compared to the one error in three hundred in a manual entry situation.
- Facilitation of remote data entry - Data can be obtained using portable units in out-of-the-way locations, eliminating manual recording and, later, manual entry into the computer system, at estimated time savings of thirty to sixty percent.
- Consolidation of events - Data collection and direct entry into the computer system are achieved with one movement of the reading device.
- Availability - Bar code technology can be implemented quickly and inexpensively, through a variety of vendors, and completely compatible with the existing computer system. (Grip, 1991, pp. 3-4)

3. Weaknesses

The principal weakness of bar codes concerns security of the symbol itself: since a bar code is a simple visual medium, it can be easily duplicated or counterfeited (Bower, 1994, p. 14). For example, a simple photocopying machine could be used to duplicate existing bar codes. Also, computer utilities are available with which anyone can produce a standard bar code, if he or she knows the underlying number or character group that the bar code is supposed to represent.

Since bar code systems rely on precise variations in light/dark reflections, the bar code symbol itself must remain clean and smudge-free, so that the bar code scanner can clearly see the lines and spaces within the symbol. However, bar codes are susceptible to the same environmental factors that affect the media on which they are printed (Bower, 1994, p. 15). For example, a bar code printed on paper or plastic can be damaged or destroyed by fire or chemicals, since the paper or plastic itself is susceptible to damage from those elements. Bar codes are also susceptible to ageing and fading; consequently, labels must be verified periodically to ensure readability (Bower, 1994. P. 15). When a bar code can no longer be read, it must be replaced.

Using bar codes requires that a person be physically present at the same location as the items to be tracked; it further requires that he or she be able to actually touch the bar-coded item (in the case of contact scanners) or at least get close to it (in the case of non-contact scanners). Even non-contact systems still require a "line-of-sight" between the scanner and the bar code.

Bar codes also have a limited data storage capability, compared to other automatic identification technologies (Bower, 1994, p. 14).

C. OPTICAL CHARACTER RECOGNITION (OCR) AND MAGNETIC INK CHARACTER RECOGNITION (MICR)

1. The Technology

Like bar coding, OCR is also a symbology or coding system. One difference, however, is that OCR characters are readable by both humans and computers: OCR characters are actual two-dimensional numbers and letters. (AIM-USA, 1992, p. BG4) Like bar coding, the characters are also read by a scanner with a light source; a matrix of detectors inside the scanner reads the reflected images of the scanned characters (Gold, 1988, p. 1-4). The detector matrix "recognizes" the pattern created by the characters, then converts the pattern to electrical impulses for transmission to a computer (AIM-USA, 1992, p. BG4). In some cases, OCR systems are incorporated into full-sheet document readers. In these readers, "full-sized typewritten or printed sheets can be fed through a device that provides the mechanical alignment necessary for good response." (Sharp, 1987, p 1-16)

Magnetic Ink Character Recognition (MICR) is closely related to--and frequently used in conjunction with--OCR. The concept is similar: both the human eye and a computer can understand the characters. The difference is that when a scanner or computer reads the print, it picks up the magnetic (not visual) characteristics of the characters. (AIM-USA, 1992, p. BG4) MICR print is most commonly seen at the bottom of checks, where the bank routing number, account number, and check number are printed with MICR-readable ink, using an OCR font.

2. Strengths

OCR is excellent for applications in which labels must be read by both people and machines (AIM-USA, 1992, p. BG4). It eliminates the need for double-labeling--having to attach one label for computers and another one for people. Since people can read OCR tags or labels, this AIT method also allows for detecting tagging errors before they become more serious problems, such as bad shipments or incorrectly manufactured products (Sharp, 1987, p. 1-16).

OCR readers and associated software are continually being improved. Some systems now available can recognize several fonts and sizes at the same time (Gold, 1988, p. 1-4) and can be used to enter previously-typed information into a computer without retyping. Used in this fashion, OCR technology can offer the user savings in labor hours and may offer monetary savings by reducing the number of computer data entry stations required.

3. Weaknesses

OCR (and MICR) is primarily a contact technology: to read the characters, a wand must be passed over them (Gold, 1988, p. 1-4), or the printed media must be passed through or under a device that can interpret it--such as the equipment financial institutions use to read account information from checks. Also, to ensure the scanner can "understand" the characters, OCR printing must comply with fairly strict guidelines to be successfully scanned. For example, many OCR page readers require that documents contain particular character fonts and spacing. (Gold, 1988, p. 1-4) The condition of the medium on which OCR characters are printed can also affect the ability of the reader to read the characters: if the paper they are on gets wet or dirty, for example, they may be rendered illegible.

Another weakness, especially with early systems, is that OCR scanning techniques are "very sensitive to character orientation with respect to scanning equipment" (Sharp, 1987, p. 1-16). Also, the "first-read" rate is substantially lower than for bar codes, so OCR applications cause more dependence on operator performance (Gold, 1988, p. 1-4). That is, OCR equipment operators may require more training because they need to know how to detect OCR errors, how to correct erroneous character interpretations, and so on.

D. MAGNETIC STRIPE

1. The Technology

Another pervasive AIT technology, magnetic stripe technology was first used in the financial services industry--on credit cards--and by various agencies for security applications. Both uses have proliferated, particularly the financial services-related card field, which has now expanded to include automatic teller cards and debit cards.

In magnetic stripe technology, data is encoded onto a magnetic medium using high and low electromagnetic charges. These charges are then read by a decoder that translates them into numbers and letters for identification by a computer. A single magnetic stripe may contain several tracks of recorded data, and it can record a significantly higher quantity of information than many other automatic data collection technologies, including bar coding. (AIM-USA, 1992, p. BG2) Each stripe has three low-density tracks for data: on track two, the most commonly used track, data is stored at 70 bits per inch (bpi); on tracks one and three, data is stored at 210 bpi (Sharp, 1987, p. 1-14). Magnetic stripe provides the user with a "flexible data format, high data density, durability and a relatively high degree of security." (AIM-USA, 1992, p. BG2)

2. Strengths

The principal strength of magnetic stripe technology is that it offers a higher data density than bar codes, and it also allows data to be altered (AIM-USA, 1992, p. BG2). A second significant strength is that it is relatively difficult to copy magnetic stripe information. For example, one could clearly not simply photocopy the media, as is possible with bar codes and most OCR-encoded items. Another strength is that there is an industry-wide standard for magnetic stripe data encoding. Consequently, cards coded on a machine made by one manufacturer can be read on any machine conforming to the standard. (Sharp, 1987, p. 1-14)

3. Weaknesses

Magnetic stripe scanners (frequently called "card readers") require a precise alignment between the scanner and the stripe, virtually eliminating the possibility of a hand-held magnetic card reader. Consequently, magnetic stripe cards cannot be attached to the exterior of boxes or other items--like bar code labels can be, for example. Instead, if a magnetic stripe card accompanies an item, it must be placed in a pouch or otherwise be configured so it can be removed from the item. To access the information on the card, a worker must remove the card from the item, insert it in a reader, then return the card to the item. (Sharp, 1987,p. 1-14) This process can take significantly more time and manpower than a system based on scanning bar codes or remotely querying radio frequency tags. Also, if cards become separated from their assigned items, or if they are replaced on the wrong items, additional accountability or other problems may be created.

Like other magnetic media, magnetic stripes are susceptible to strong electromagnetic fields, so cards or other devices with magnetic stripes on them must be protected from strong magnetic fields. (Sharp, 1987, p. 1-15). Because of the relatively "delicate" nature of the magnetic stripe and the requirement for a precise alignment between the scanner and stripe, magnetic stripe cards may not work properly if they are bent or warped, or if the stripe is compromised by friction or some other circumstance. Also, while the data density is higher than bar codes, it is still quite limited.

E. SMART CARDS

1. The Technology

Smart cards are credit-card sized plastic cards that have one or more microchips imbedded in them. The cards are programmable and carry large databases. Because of their large data carrying capacities, smart cards are ideally suited for multiple services use. For example, "a smart card can be used ... as a bank card, a frequent buyer card, and a healthcard all in one because it has the information storage capacity of a PC." (AIM-USA, 1992, p. BG 4)

2. Strengths

Smart cards can eliminate the need for multiple cards (such as credit, debit, and telephone cards), because they can contain generic information about their owners--the type of information that is typically repeated from card to card. Proponents suggest they can even be used as "pocket databases," since essential data such as emergency health data and other information can be stored on them. If programmed to do so, smart cards can "defend themselves against unauthorized use by becoming inoperative if a password is not correctly entered." (Gold, 1988, p. 1-6)

3. Weaknesses

The principal weakness of smart card technology is the relatively high cost of the card and the supporting hardware and software (Bower, 1994, p. 43). A related weakness is the lack of a widespread supporting infrastructure: in contrast to magnetic stripe cards, there are fewer smart card users, fewer smart card readers, and so on--in essence, there is a degree of inertia discouraging rapid expansion of the market. Also, like magnetic stripe cards, smart cards can be damaged (and rendered non-functional) by bending or improper use. They can also be affected by chemicals and extreme weather conditions. (Bower, 1994, p. 44)

F. OPTICAL/LASER CARDS

1. The Technology

An optical card (often called a "laser card") is a credit-card sized object similar to a smart card. Data storage and retrieval from an optical card is based on optical data storage technology. In fact, the core technology behind these systems is the same type of laser device found in home Compact Disk and laserdisc players. Each card has a recording surface --a thin, metalized coat about 1mm thick--encapsulated between two protective layers that form the outside of the card. Information is recorded on the card using a narrow laser beam focused onto the recording surface. The exact method of recording depends on the particular system used, but in general, the laser "writes" information to the recording surface digitally by imprinting a series of light and dark areas on the disk. Reading an optical card requires a reader or scanner that incorporates a laser, which detects light and dark reflections from the metalized surface and interprets the reflections as digital data (binary ones and zeros). (Lesser, 1993, p. 27)

Currently, optical memory card data capacity ranges from 2.8 megabytes (MB) to 6.6 MB, approximately 2,400 pages of text. (Bower, 1994, p. 31) Optical systems are found in several forms including Write-Once-Read-Many (WORM), and writeable/erasable media. The WORM format, in which data cannot be erased, offers the user an "audit trail" capability. When new data is written to the card, it can only be written to an unused portion of the card; all previously-entered data remains on the card, so the chronology of changes to the data can be tracked.

2. Strengths

Optical cards are very durable, compared to other AIT, such as bar codes and magnetic stripe. Since an optical card is physically "etched" by the laser when data is recorded on it, the card is not affected by electromagnetic interference. The card can also withstand temperature extremes (-40 to 212 F), and the outer protective layers are resistant to "various chemical solvents, dirt, dusty environments, and severe impact." (Bower, 1994, p. 32)

Other strengths include the high data storage capability; the audit trail capability; the existence of established standards for the technology; and the ability to complement other technologies, such as RF identification systems. (Bower, 1994, p. 33)

3. Weaknesses

The principal weakness of this technology compared to bar code and magnetic stripe card technologies is the cost of the card (in general, \$5 - \$8 per optical card, compared to \$.10 -\$.25 for bar code and \$.85-\$1.50 for magnetic stripe) and the costs associated with the increased complexity of the hardware, software, (Bower, 1994, p. 34) and perhaps even specialized training associated with the optical system.

G. VOICE RECOGNITION

1. The Technology

Voice recognition technology is designed to allow data entry when an operator's hands and/or eyes are pre-occupied. In a voice recognition system, the operator speaks into a microphone, and each word or phrase he uses is recognized by the system and converted into electronic impulses for the host computer to process. Like other AIT technologies already discussed, this technology is also based on pattern recognition; however, instead of recognizing visual patterns, this particular computer system recognizes words in a pre-programmed vocabulary. (AIM-USA, 1992, p. BG4)

Two types of systems are available: speaker-dependent and speaker-independent. With speaker-dependent systems, the matching pattern the computer uses is based on a specific operator's voice characteristics. Speaker-independent systems, on the other hand, depend on "'averaged' patterns drawn from a large sample of voices." The former system is more accurate; the latter is more flexible, since it can be used by more people. (Gold, 1988, p. 1-5)

2. Strengths

Voice recognition systems are "ideal in circumstances in which the operator's hands and/or eyes are occupied, such as in a laboratory setting." (AIM-USA, 1992, p. BG4) They are also useful in situations in which automation is necessary, but keyboards or other input devices are not practical. They are also useful when operators are not "computer literate." (Gold, 1988, p. 1-5)

3. Weaknesses

As mentioned above, the systems that are most accurate (speaker-dependent) are really only effective when used by a single person; and the systems that allow for more users (speaker-independent) are not as accurate, because they are based on "average" sounds.

H. RADIO FREQUENCY IDENTIFICATION

1. The Technology

Radio frequency identification is typically accomplished through Radio Frequency (RF) "tags," reusable transponders that are placed on items to be tracked. Radio frequency identification technology is centered around four components: a transponder, a reader, an antenna, and a host computer. The four RF components generally work together as follows: a reader interrogates the transponder with a power burst; the burst "charges" the tag; and the tag returns a signal that carries data back to the reader. The computer controls the reader and manages data. (Signal, 1994, p. 92)

There are two basic types of RF tag systems: active and passive. Both systems operate in essentially the same way:

> (a) Tags are pre-encoded with data that uniquely identifies the tag (or the item it is mounted on, such as a truck or container).
>
> (b) When prompted by certain stimuli, the tag transmits the data to an RF reader, which in turn transmits the information to a host computer.
>
> (c) The computer combines data received from the tag with other database information to yield meaningful management information (such as the location and contents of a particular container).

Two principal differences between active and passive RF tags concern (1) whether the information encoded in the tag can be changed, and (2) whether the tag has a power source. Passive tags are the simplest type, because they have no power source and are encoded with data that cannot be changed. Active tags, on the other hand, have power sources and can be programmed to transmit whatever information the user desires.

A passive tag is basically a small circuit board with tiny receiving and transmitting antennae. When the tag is interrogated, it receives the incoming signal, then echoes back a portion of the signal to the reader. The "echo" carries the identification or other data stored on the passive tag (Schwind, 1986, p. 84.). The data the tag transmits is a function of the tag's physical manufacture: the actual etching patterns in the circuit chip determine the code or number that will uniquely identify the tag (Hill, 1985, p. 76). Thus, while passive tags can be reused (moved from one item to another), the encoded data can never be changed. Because of the permanent nature of this data, passive tags are sometimes referred to as "license plate" tags. And for the same reason, the encoded data on passive tags is typically used as an "index" code that can be cross-referenced with more detailed information stored in a database. For example, a passive tag moving past a reader might uniquely identify a truck and its location, but it will not reveal the cargo on the truck--for that information, the truck number will have to be cross-referenced with a database that shows what was loaded on the truck.

In contrast, active tags are basically low-powered integrated circuits, with a transmitter, receiver, and some memory. Active tags include a self-contained power source--such as a lithium battery--which allows "any combination of longer operating range, read/write capabilities, greater data storage capacity, and internal programming." (Torres, 1994, p. 36) These tags are clearly more versatile than passive tags; however, the technology that allows them to operate from an internal power source, to store more information, and so on, makes them more expensive than passive tags. For example, Savi Technology, Inc. sells its "SealTag," which is *active* by the above definition, for about $190, while its passive "TyTag" (discontinued 1995) was available for about $80. Clearly, active tags should only be considered for applications in which the need for longer range or larger memory outweighs the additional cost.

2. Strengths

A major strength of both active and passive tags is that the service life is virtually unlimited: in some cases, the item to which the tag is attached can actually wear out or be used up before the tag needs to be replaced. (With active tags, batteries will have to be replaced--probably after five years--but the tag itself will last much longer.) Tags are typically encapsulated in a manner that seals out moisture, dirt, oil, and so on. Tags designed for the exterior of vehicles or heavy equipment are normally mounted in a sturdy casing designed to withstand weather and other environmental changes. And since the tags contain literally no moving parts--and the circuits have been designed for heavy-duty use--rapid movement or jarring does not affect them. (Hill, 1985, p. 77)

Another strength of RF tagging is the flexibility of placement of the tags and reader. First, the reader does not have to come in contact with the tag, as is the case with other automatic identification technologies. A card with a magnetic stripe, for example, must come in contact with a reader (such as an automatic teller machine) in order to transfer data. Also, for RF tags, there is no line-of-sight requirement. Some other automatic identification technologies (such as bar coding) require an unobstructed line-of-sight between the reader and the coded media. Consequently, an RF tag can be placed on any side of an item being tracked, such as a container. A related strength of RF tags is that they can be interrogated in motion: since there is no line-of-sight or contact requirement, the item being identified does not have to stop. Finally, the combination of all the above strengths makes it possible for RF tags to be used in special situations that could not be handled by other automatic ID technologies--such as darkness or underwater (Fales, 1992, p. 14).

3. Weaknesses

The principal drawback to RF tag systems is cost: the total cost of implementing an RF system can be much more than the cost of implementing other automatic ID systems, such as bar coding. The technology employed in radio frequency systems is more sophisticated than that involved in other automatic ID systems, and RF technology also has not had as many years to mature as other technologies. Consequently, the hardware and software required to operate an RF system can cost significantly more to purchase than equipment for other systems.

Another weakness of RF tag systems is that some are subject to radio interference, from outside sources and from multiple tags responding simultaneously. RF tag types that *are* susceptible to interference are best used in applications requiring identification of moving objects separated by a reasonable distance (Bushnell, 1988, p. 2-5).

Some RF tag systems can also be affected by metal objects that come between the reader and the tag. However, "tuning" (frequency selection) and optimal placement of the reader and the tag can correct this problem (Bower, 1994, p. 30). For example, this problem can be mitigated in some applications by placing the reader high on a pole or wall, and the tags on top of the items being tracked, such as boxes being moved around a warehouse. Another solution would be simply using a different type (i.e., brand) of RF tag/reader system; according to the vice president of marketing for Hughes Identification Devices, "On an eight lane RF Identification-based toll road, one reader [such as those made by Hughes] can catch 50 cars spread four lanes wide and bumper to bumper traveling 100 miles-per-hour from each direction at once." (Small, 1992, p. 47) Even allowing for hyperbole, it is clear that tag systems do exist that are not affected by metal, high speed movement, or many tags responding at once. Another firm, Savi Technology, has developed a patented protocol, which they call "Batch Collection," that allows an interrogator to receive near-simultaneous responses from up to 3,000 tags within the interrogator's range (Savi Technology (c), 1996).

4. Applications

RF tags are already widely used in civilian applications. They have been fielded for select military missions and are being tested for more widespread military use. As Gene Schwind states in an article in *Material Handling Engineering*, an RF tag "can be used to code animals, places, and things. It can be placed where no other code forms can be considered. It has a long life and almost endless capability." He also discusses several interesting examples, a few of which are summarized below.

- Photo security badges can contain hidden RF codes that selectively permit employees to open gates, doors, and so on.
- Livestock can be outfitted with collar RF tags that record movements and allow access to feed.
- Laboratory mice can be identified through tiny transponders injected under their skin.
- Tags on vehicles can open gates, direct a particular vehicle to a specific loading dock, record tolls, and actuate refueling pumps. (Schwind, 1987, p. 100).

a. *Transportation Improvements*

Some commercial transportation firms have already firmly incorporated RF technology into their operations. For example, as early as 1991, Matson Intermodal implemented an RF tag identification system at its Honolulu terminal. In the Matson operation, an RF tag is attached to every truck that supports the terminal. As a truck enters the terminal gate, a fixed antenna interrogates the transponder. The transponder's response automatically inputs time and identification data into the firm's database. Later, as the truck approaches the exit gate, another antenna determines which truck is approaching, then causes an automated system to generate a printout for the driver that documents his activities and time spent at the terminal. Matson's president estimated that implementing this system--which reduced a one-minute gate stop to a fifteen-second gate stop--saves the company over 3,000 work hours annually. As an additional feature, the system generates a "flag" for vehicles that are in the terminal area for too long, so a supervisor can investigate and provide any assistance necessary. (Kalleres, 1993, p. 31)

b. *Improving Processes*

Besides merely identifying items or allowing and monitoring access, RF tags can also be coupled with other technologies to improve the efficiency of certain processes. RF tags currently on the market have already been used to automate warehouses and manufacturing flow. For example, a typical warehouse scenario might be as follows:

traveling bins filled with items to be distributed among numerous trucks are identified and routed to the appropriate location through the use of RF tags *and automatic transport equipment* (Gold, 1988, p. 1-2) (emphasis added).

This example highlights the point that RF tags do not perform amazing feats in and of themselves, but when properly integrated into a complete system, they can make a tremendous impact on the overall efficiency of an operation. Figure 1 shows a typical assembly line application.

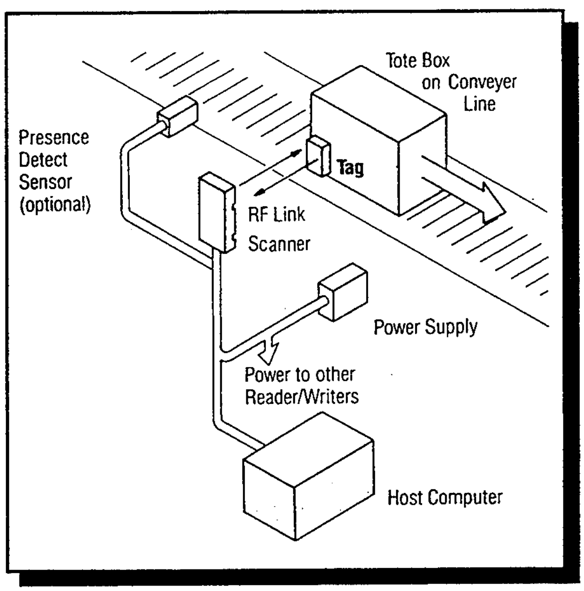

Figure 1 Typical Assembly Line RF Tag Use
(Schwind, 1986, p. 86)

As Alan Gold wrote in 1988, "Accuracy [for this type of warehouse application] approaches 100 percent. This application can eliminate the need for human interference in the sorting and moving processes, and speed up throughput considerably."

(Gold, 1988, p. 1-2) His analysis was correct; since then--as occurs with most developing technologies--the effectiveness of available systems has continued to improve. In fact, in some applications today, companies are discovering that RF tags and the information systems they feed have the potential to transform the very nature of their businesses. For example, Schneider, one of North America's largest trucking firms (with over 9,000 trucks), has incorporated RF tagging and intransit visibility concepts into its operations so thoroughly that it has been described as "an information system masquerading as a trucking line." In fact, CEO Don Schneider says, "People get the mistaken impression that our business is running trucks." (Solomon, 1994, p. 54)

c. *Rail Industry*

In another transformational application, the railroad industry, long a slave of turn-of-the-century procedures, has made a technological leap forward through the widespread installation of RF tag systems. The Association of American Railroads recently required member railroads to install what the industry terms "Automatic Equipment Identification" (AEI) transponders. By mid-1995, 1.3 million freight cars and 22,000 locomotives had been equipped with RF tags, and 1,200 track-side sites were equipped with tag readers. The freight car figure represents an impressive 100% of all rail freight cars. (White, 1995, p. 2) This use of RF tags will undoubtedly improve the accuracy and timeliness of the data railroads use to manage their assets. To the extent individual railroads incorporate this new information when making hourly and daily management decisions, the AEI system should result in more efficient overall operations. Improved efficiency, in turn, should enhance the rail industry's competitive position relative to trucking.

d. Highway/Toll Projects

Some state governments have also taken the lead in attempting to create efficiencies through the introduction of RF systems. Currently, at least three major projects involving highway or toll-road use of RF tags are underway: Advantage I-75, HELP, and the Riverside Freeway project. The Advantage I-75 program is scheduled for testing on a section of Interstate 75, then for later deployment among 22 weigh stations along the highway, which stretches from the Canadian border above Michigan to Miami. On the other side of the country, HELP--the "Heavy-Vehicle Electronic License Plate Project"--is scheduled for testing along portions of Interstates 5 and 10, covering a route that runs from the state of Washington to Texas.

Both projects are designed to demonstrate electronic clearance across state and national borders. Each program eliminates the requirement for trucks to stop at weigh stations or ports of entry for standard weight, credential, and safety inspections. Drivers will be allowed to bypass checkpoints, because RF transponders attached to the trucks will transmit necessary information to automated receivers positioned at "pre-clearance sites" before each check point. (Richman, 1994, p. 26)

In the third project mentioned above--the Riverside Freeway project--California authorities recently completed installing an "electronic toll and traffic management system" on SR-91, a toll road expressway in the Riverside area, in an effort to control congestion. The system uses a variety of technologies to accomplish several functions, but of particular interest for this discussion is the use of RF tags to automatically collect toll charges. Drivers desiring to save time by using the expressway are required to prepay a certain toll amount and attach read/write RF transponders to their vehicles. Then each time they use the expressway, they are automatically charged a toll, without stopping: their RF tags will be read and their prepaid "accounts" decremented. (Masciola, 1995, p. 1)

These three highway applications may well foreshadow a *transformation*--in terms of driving habits, traffic patterns, and so on--in the same way that the Schneider and railroad examples represented transformational change in the operations of a specific firm or industry. First, both Advantage I-75 and HELP should have profound impacts on the motor carrier industry, through increased efficiency: with fewer mandatory stops, drivers can devote more of their operational days to actual driving. The projects will also decrease traffic congestion in and around checkpoints and weigh stations (notorious sources of congestion), and thus may alter previously-existing traffic patterns for many miles. Peak rush hours may even shift, as drivers realize they do not have to schedule their time on the road to "avoid all those trucks." True, major interstates will probably always have a large amount of truck traffic, but there is a big difference (with respect to traffic flow) between trucks traveling at the speed of traffic and trucks slowing and stopping and then later trying to merge back into traffic.

The SR-91 project will have an even more direct effect on individual drivers in its area. As with the first two projects, it should yield a more efficient traffic flow, since drivers will not have to slow down and stop at toll plazas, but this project should also make driving "easier" for the public in other, down-to-earth ways. After their initial decision to participate in the program (and thus be able to use the expressway), drivers should actually have fewer driving concerns than before. For example, they will never again have to worry about finding change for tolls before they leave home or while they are driving, or about whether to use the automatic or "receipt required" lane at toll plazas.

III. THE ARMY OF THE 21ST CENTURY

A. THE CONTEXT

With the end of the Cold War and the collapse of the Soviet Union, the United States stands alone as the world's only superpower. As befits its status as the remaining superpower, the U.S. also possesses the pre-eminent military in the world; no other military can match the training, lethality, and power projection capabilities of the U.S. military. However, a wide variety of dynamics--inside and outside of the nation--challenge the United States' ability to maintain military pre-eminence.

1. Internal Pressures

a. Budgets

Many of the dynamics and pressures within the nation are fiscal in nature: the military services face strong budgetary pressures today due to sharp reductions in Department of Defense budgets. For example, the Army budget for fiscal year 1995 was only $61.1 billion, a thirty-three percent decline from fiscal year 1990's $90.8 billion budget (in constant 1995 dollars). Placing further pressure on the service, the modernization component of the Army budget--the part dedicated to developing and procuring weapon systems--plummeted fifty-one percent (from $22.2 billion to $11.4 billion) over the same time. (Baker, 1995, p. 36)

b. Downsizing

A related dynamic affecting the services is Congressionally-mandated downsizing. The Army, for example, has been directed to reduce its active duty strength to 495,000 soldiers in ten divisions by the end of fiscal year 1996. This is a thirty-six percent reduction from the 770,000 soldiers and eighteen divisions that comprised the Army in 1989. (Steele, 1995, p. 46) The military's new mission orientation (rapid-deployment instead of forward-deployed) also creates additional pressure, since each service essentially must be prepared to perform a wider variety of missions with a smaller number of personnel and less funding than during the Cold War years.

c. Roles and Missions Changes

In November 1993, Congress convened a special commission to study the "roles and missions" of the respective military services and to prepare recommendations about the future defense structure and mission allocation among the services and defense agencies (10 USC, 1994, p. 342). The commission findings were published in May 1995, but it will take longer time than has elapsed thus far for the services to understand--and feel--the full impact of the commission's findings. There are two reasons for this delay: First, the commission's findings were recommendations, not mandates. Second, the recommendations were presented as general directions in which the Department of Defense should head; commission members purposely avoided preparing a "series of 'put and take' statements that rearrange U.S. forces from one Service to the other." (Commission on Roles and Missions, 1995, preface) Consequently, the legislation that Congress ultimately passes may or may not result in significant changes to the structures or missions of the respective services. For now, then, there is a degree of uncertainty about precisely which functions each service will be expected to perform in the future.

2. External Pressures

a. Multi-polarity

Today's world is very different from the bipolar world of the Cold War, which was clearly dominated by the struggle between the United States and the Soviet Union. During the Cold War, the United States focused its security strategy on "containment" of communist expansion and on preparation for war with the Soviet Union. Of the then-eighteen active and ten reserve Army divisions, twenty-four were committed for fighting Soviet forces in Europe; the remaining divisions were identified for fighting Soviet forces or allies in other theaters (Sullivan, 1995, p. 3). Today, after the collapse of the Soviet Union and with the rise of regional "strongmen," the U.S. can no longer focus its security strategy on a single threat. Consequently, the military cannot train or organize for a single threat; it must instead prepare for a wide variety of conflicts, wars, and Operations Other Than War (OOTW).

b. Rising Nationalism

Nationalism has replaced communist ideology as "the leading cause of interstate and intrastate conflict." (TRADOC (b), 1994, p. 2-1) The chief threat of the rising nationalist movements is that they "can erode the power and legitimacy of states," because "[u]nder the guise of transnationalism, these movements may also serve as an excuse for regional strife, as one nation seeks to extend its authority over all members of its ethnic group." (TRADOC (b), 1994, p. 2-1)

c. Technology Growth

Technological developments are progressing at a geometric pace, disrupting established ways of doing business. American technological superiority is by no means guaranteed, because revolutionary changes in critical technologies could lead to a global reordering of military or economic power. (TRADOC (b), 1994, p. 2-2) In particular, major advances are being made in the way information is collected, communicated, and used: the microprocessor, which "supplement[s] brain power with the near-instantaneous power of electronic computation" (Sullivan (b), 1995, p. 3) is revolutionizing our society. It is changing not just the way we live, but also the way we will probably fight in the future. Many people believe we are entering a new, post-industrial age: the Information Age. (Sullivan (b), 1995, p. 3)

d. Weapons Proliferation

Today, more than fifteen third world countries have ballistic missiles; more have begun programs to develop them. Further, many countries that either have or are acquiring ballistic missiles also possess weapons of mass destruction. The trend is clearly towards systems of increasing range, lethality, and sophistication. The director of the Central Intelligence Agency, R. James Woolsey, reported to Congress that after the year 2000, several countries hostile to the United States might be able to acquire ballistic missiles that could threaten the continental United States. He added, "We are likely to see several Third

World countries at least establish the infrastructure and develop the technical knowledge that is necessary to undertake intercontinental ballistic missile and space launch technology." (Meadows, 1995, p. 18)

B. THE VISION: FORCE XXI

1. The Architect

In the context of these dynamics, Army leaders have begun shaping the Army of the future with a bold initiative for re-invention called "Force XXI." The chief architect of this vision for the Army's future has been General Gordon Sullivan, Army Chief of Staff from 1991 to 1995. The following quote from his article "America's Army--Focusing on the Future," captures the essence of Force XXI:

> Force XXI is not a unit; it is not even a unit design. Rather Force XXI is a comprehensive approach to redesign the force--organized around information--to be inherently vertical and flexible. It will be capable of achieving success--decisive victory--across a broad spectrum of operations. Force XXI stretches from factory to foxhole, reflecting a focus on the battlefield at every level. Force XXI is about the integration of information age technology across the spectrum of the entire force. Force XXI is about the seamless employment of active and reserve components' capabilities. (ODCSLOG, 1995, p. 3-1)

2. Characteristics

Since General Sullivan originally presented his vision for the future in 1994 (ODCSLOG, 1995, p. 2-3), several official and unofficial publications have added to the groundswell of discussion surrounding Force XXI. One key publication is TRADOC Pamphlet 525-5, Force XXI Operations. The intent of the pamphlet, which is subtitled "A

Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century," is to describe

> the conceptual foundations for the conduct of future operations in War and OOTW involving Force XXI--the U.S. Army of the early twenty-first century ... [and to provide] ... a vision of future conflict for the development of supporting concepts, programs, experiments, and initiatives (TRADOC (b), 1994, p. i).

In presenting this "conceptual foundation," the pamphlet describes the future Army in terms of five essential characteristics, summarized below:

a. Doctrinal Flexibility

Army doctrine will have to be flexible, because the "strategic landscape" of the future will be multifaceted and have great potential for "surprise across the operational spectrum." Key to this flexible doctrine will be the Army's quality leaders and soldiers: "Practiced in application of principles in varied scenarios, our soldiers and leaders will be able to continually adapt tactics, techniques, procedures, and organizations to meet future requirements." (TRADOC (b), 1994, p. 3-1)

b. Strategic Mobility

The Army must be able to provide a force "at the right place at the right time with the right capabilities." Doing so will require a skillful combination of "anticipation, movement, and ... pre-positioning." (TRADOC (b), 1994, p. 3-2) In particular, the pamphlet notes that initiatives should focus on the portions of mobility that can be improved through new information systems, broadcast intelligence, or information about other battlefield functions. (TRADOC (b), 1994, p. 3-2)

c. *Tailorability and Modularity*

A variety of factors will demand that forces be modular, so they can be task-organized for a specific mission or contingency. These factors include strategic lift limitations, time limits, other service capabilities, and limits on the number and type of units in the Army. (TRADOC (b), 1994, p. 3-2) Also, the "leader to led" ratio must be flexible for specific missions (TRADOC (b), 1994, p. 4-5).

d. *Joint, Multinational, and Interagency Connectivity*

In order to "to fully execute full-dimensional operations throughout the depth, height, width, and time of the particular battlespace," the Army will need to use other service assets, such as strategic lift. Conversely, the Army must be prepared to perform certain unique functions, such as port security and clearance, for the other services. (TRADOC (b), 1994, p. 3-2)

e. *Versatility in War and Operations Other Than War (OOTW)*

The nation cannot afford to maintain different armies for different mission-types. Instead, the priority will continue to be maintaining an army trained and ready to win the land battle, knowing that well-trained and disciplined units, "provided with sufficient time and resources to train, can transition to OOTW missions as required." (TRADOC (b), 1994, p. 3-2)

C. THE LOGISTICS

1. Additional Dynamics

As the entire Army evolves into an information age force, its logistics system must also evolve, in order to ensure critical support is provided on the battlefield where it is needed and when it is needed (Wilson, 1995, p. 14). While Army support forces will be subject to the same pressures as those described above for the operational element of Force XXI, a few dynamics not already addressed deserve mentioning. (These items are drawn from assumptions about the future logistics environment contained in the DoD Logistics Strategic Plan.)

a. Need For Agile Logistics Support

The shift from the Cold War orientation towards global conflict to the current and future orientation towards regional conflicts requires agile logistics support. The shift towards force projection also demands agile support. As the DoD plan states,

> Agility requires greater mobility, complete asset visibility, more dynamic workload management across logistics elements in order to provide a rapid response to changing requirements, and improved management information to assert necessary control over employment of logistics resources. The process that begins with the identification of a requirement or need, and ends when the customer accepts delivery of a weapon system as operationally ready, must be streamlined. (DUSD(L), 1995, p. 6)

b. Importance of Information

Logistics information has been a significant commodity of the defense logistics system for many years. However, as resources decline, and as deployment lead times for the rapid-deployment force shorten, the demands for on-line, accurate information and reliable communications will increase. (DUSD(L), 1995, p. 7)

c. *Diminishing Industrial Base*

The industrial base upon which defense logistics relies will continue to experience "an overall reduction in defense logistics-related work, diminishing sources of manufacture, potential loss of domestic sources of supply, or transfer to off-shore sources." These circumstances may lead to several challenges, including a decreased capability for the industrial base to surge. Challenges of this significance will require that political and economic considerations be integrated with logistics planning. (DUSD(L), 1995, p. 7)

d. *Strategic Transport Constraint*

Ships and aircraft capable of transporting military equipment to both improved and unimproved locations will continue to be a constraint to deploying Army forces. It will become essential that logistics information is managed effectively, so duplicate and erroneous shipments are minimized. Further, as transportation--instead of large inventories or pre-positioning--becomes the principal determinant of the Army's ability to move and receive materiel on time, having accurate information about assets in-transit will become critical. (DUSD(L), 1995, p. 7)

2. Army Logistics Today

a. *Echeloned Support*

Today's Army logistics system has evolved over many years. At the heart of the current system is the concept that support is provided at three distinct echelons: strategic, operational, and tactical. The Army Strategic Logistics Plan defines these echelons as shown in Figure 2.

- Strategic Logistics–includes the Nation's organic industrial base and DoD's link to its military forces. This level is primarily the purview of the DoD, individual Services, and non-DoD governmental agencies, with support from the private sector. The strategic logistician's focus is on requirements determination, personnel and materiel acquisition, prepositioning, stockpiling, strategic mobility, deployment, redeployment, and demobilization. Based upon current DoD infrastructure reduction goals, this level could experience continued corporate consolidation as automated logistics systems are already migrating to DoD standard platforms, language, and data.

- Operational Logistics–ties tactical requirements to strategic capabilities in order to accomplish operational plans. It encompasses support required to sustain joint/combined campaigns and other military activities within an area of responsibility. Military units, augmented by DoD civilians, civilian contractors and host nation resources, constitute the organizational structure found at this level. The primary focus of the operational logistician is on reception, discharge, onward movement control, distribution, reconstitution, and redeployment.

- Tactical Logistics–the synchronization of all logistics activities required to sustain soldiers and their systems. Military units, organic to the deployed tactical force, constitute the bulk of the logistics organizations at this level. However, the organization may include civilian contractor personnel and DoD personnel. The focus of the tactical logistician is on the primary logistics war fighting support functions of manning, arming, fueling, fixing, moving, and sustaining the soldier and his equipment.

Figure 2 Army Logistics Echelons (ODCSLOG, 1995, p. 2-5)

b. Limitations

While the current logistics structure has served the Army well in many conflicts and operations, it does have several limitations, including:

- Sequential echeloned financial and logistics data processing
- Redundant processing of identical data elements; no baseline for source data automation
- Processes and business practices based on hierarchical structure

- Less than full asset visibility; diffused ownership
- Inventory/requisition-based support
- Less than effective satellite-based communications capability (ODCSLOG, 1995, p.2-6)

3. Army Logistics Tomorrow

a. Force XXI Logistics

TRADOC Pamphlet 525-200-6, Combat Service Support, provides a clear definition of Army logistics as it will have to function in the context of Force XXI:

> It includes both the logistics force and the sustainment base. Its purpose is to maintain readiness and sustain Army forces in combat operations. Therefore, the holistic purpose of logistics is to support mobilization, deployment, reception and movement, sustainment, reconstitution, redeployment, and demobilization of military forces. In this sense, logistics also includes such functions as manning the force, financing the force, and providing health services for the force. The orientation of logistics must remain on soldiers and their weapons systems. Consistent with military operations, logistics operates in a continuum across strategic, operational, and tactical levels. It generates power at the tactical level in the form of manning, arming, fueling, fixing, moving, and sustaining the soldier. (ODCSLOG, 1995, p. 3-2)

b. Strategic Plan

The Army's framework for transforming the above definition into reality is the Army Strategic Logistics Plan (ASLP). The plan lays out the Army view of future logistics and is intended to provide a medium for synchronizing "the efforts of individual logistics organizations, automated systems, processes, technology insertions, and policies in accordance with the strategic direction of the Army." (LIA (a), 1995, p. 2) As General Sullivan states in his memorandum forwarding the plan, the ASLP is designed to serve as "our road map to take logistics into the 21st century." (Sullivan (a), 1994, p. 1) The ASLP provides the logistics vision that was agreed upon by the logistics "Triad," which is composed of the Army Deputy Chief of Staff for Logistics, the Deputy Commanding General of Army Materiel Command, and the Combined Arms Support Command (CASCOM) Commander. Their vision is that the emerging logistics system will be a "seamless logistics system capable of providing world-class logistics support for America's Army in any scenario." (LIA (a), 1995, p. 5) To help with the design of new logistics strategies supporting this vision, the ASLP identifies nine logistics objectives, shown in Figure 3.

- Create a single, seamless logistics system for the Force XXI Army and beyond
- Standardize operating practices and supporting automation and communications architectures
- Reengineer logistics functions and training for America's Army
- Establish visibility of stocks in storage and in-transit
- Develop and implement an integrated distribution system
- Develop effective mobilization, strategic mobility, deployment/redeployment, reconstitution, and joint logistical capabilities to meet the National Military Strategy
- Design, develop, and field flexible, modular, logistics force structures to support operations across the spectrum
- Develop logistics measures and standards of performance (MSOP) based on tactical requirements and associated operational MSOP
- Institutionalize a system of innovation

Figure 3 Army Strategic Logistics Objectives (LIA (a), 1995, p. 5)

c. *Battlespace Logistics*

At the heart of the emerging logistics system--the system that will accomplish the objectives listed above--is the concept of "battlespace logistics." This term is derived from the 1993 version of Army Field Manual (FM) 100-5, *Operations*, which introduced the concept of "battlespace operations" as the successor to "AirLand battle," the operative concept from earlier Operations manuals. Battlespace logistics essentially refers to a logistics continuum comprised of "soldiers, civilians (DoD and contractors), organizations, modular support forces, and an integrated, intelligent, and networked information system." (LIA (a), 1995, p. 6) Other characteristics of battlespace logistics, as identified in the strategic logistics plan, are shown in Figure 4.

Essentially, Army leaders envision that battlespace logistics will function as a continuous pipeline "from the factory to the foxhole" (CSA, 1995, p. 1) Support will not depend on discrete echelons--as with current Army logistics--but will instead be operated by a chain of logistics commands that begins in the United States and extends as far forward as necessary to support the maneuver units on the battlefield. A graphical representation of battlespace logistics is presented in Figure 5; certain terms from that figure are explained below:

(1) National Provider. The Army National Provider is a single command, with a senior logistician as its commander, that is responsible for the seamless pipeline that extends from the national level "all the way down to a broken tank at the forward line of own troops (FLOT)." (Robison, 1995, p. 22) The national provider brings the full power of the national

logistics base (DoD Civilian resources as well as the U.S. industrial base) to bear, in order to satisfy the logistics needs of the supported Commander-in-Chief (CINC). It represents the national-level "capability to manage, resource, and control the materiel management, maintenance, procurement, distribution, and deployment functions for the Army or other joint and combined customers." (LIA (a), 1995, p. 9)

- Single logistics system
- Fully synchronized and compatible with both active and reserve combat and combat support organizations
- Operates under a concept of assured support...a predictive push and responsive pull type interface between provider and customer with the assurance of required support on time, where required, with required quantities
- Joint/combined capable
- Non-hierarchical structure with multi-functional components
- Flexible, modular organizational elements
- Intelligent, value-added, networked system electronically linked with compatible, assured communications operating in real-time
- Visibility of assets throughout the system
- Digitized, space-based, simultaneous, and anticipatory
- Cost effective and transparent to the user
- Knowledge-based vs. echeloned sequential processing

Figure 4 The Characteristics of Battlespace Logistics (LIA (a), 1995, pp. 6-7)

(2) Battlespace Logistician. In the theater of operations, a battlespace logistician will command a major subordinate command of the national provider. This subordinate command will provide in-country logistics command, control, and coordination.

It will replace the traditional operational level of logistics and will probably be jointly-staffed. The battlespace logistician will be responsible to the supported CINC or the joint task force (JTF) commander. (Robison, 1995, p. 22)

(3) Battlespace Command. Further forward in the area of operations, a battlespace command will be headed by the senior logistician in that area. This command will serve as the forward logistics command, control, and coordination headquarters and will be responsible to the JTF commander. (Robison, 1995, p. 22)

(4) Battle Command Logistician. Still further forward--in the JTF area of operations--the battle command logistician will head another logistics organization. At this level, the logistician will be able to tailor the pipeline in various ways based on local requirements. For example, he will be able to adjust the number and type of support teams providing support in the area. Based on factors such as unit type and size and current mission, the battle command logistician can add or subtract support teams with capabilities ranging from personnel support to tank or artillery maintenance. Since the support teams will be modular, they can be attached to other organizations. A postal support team, for example, could be attached to an ordnance headquarters company; the ordnance company would support the postal team and its equipment, and the postal team would manage the mail. (Robison, 1995, p. 23)

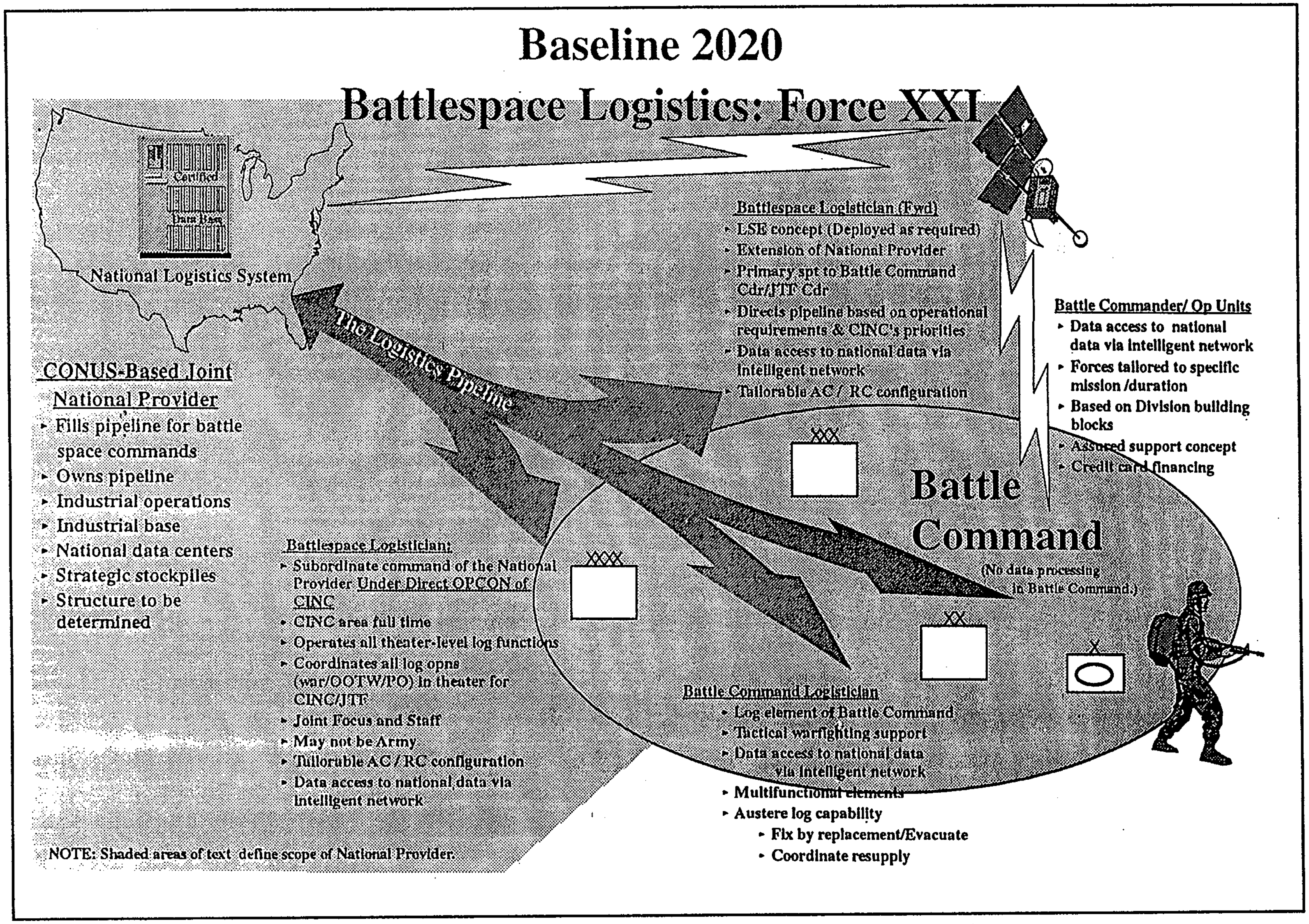

Figure 5 Battlespace Logistics (ODCSLOG, 1995, fig. 3-2)

4. Asset Visibility

For battlespace logistics to become a reality, information will clearly be all-important. Without accurate, timely knowledge of where personnel and materiel are, no element of the pipeline can function properly. None of the key players, from national provider to battle command logistician, will be able to manage, control, or coordinate the logistics flowing through their portion of the pipeline. With an understanding of this absolute need for accurate, distributed information, senior DoD and Army leaders have mandated programs supporting two key concepts: Total Asset Visibility (TAV) and In-Transit Visibility (ITV). TAV refers to knowledge about the location and status of defense resources, such as personnel and materiel, at all times. ITV refers to the movement component of TAV--knowledge about personnel and materiel that are flowing through the logistics pipeline. When ITV is combined with information about resources in-process and in-storage, total asset visibility is achieved. Asset visibility is viewed as essential for defense for three reasons. First, as mentioned previously, defense assets have been drastically reduced: there are fewer people, fewer units, and less equipment to accomplish necessary missions. Consequently, it is important to carefully manage, move, and employ the limited assets that are available. As retired Army general William Tuttle commented,

> The fewer the assets, the more vital each shipment becomes. ... So my basic question is, how do we manage without ITV? Planning is important, but flexibility is critical. Our high-tech force requires thousands and thousands of repair parts. How do we manage these vital assets without ITV? (Kalleres, 1993, p. 25)

A second reason asset visibility is critical concerns the changing concept of how U.S. armed forces--particularly the Army--will deploy and fight future wars. As the Army becomes a power-projection force, future conflicts will require the movement of more equipment and personnel than planned for in previous war plans, and there will be little time for correcting shipping errors or finding lost equipment. As Vice Admiral Kalleres commented,

> Whether it be Operation Restore Hope or the Crimean War, someone has reached into a box for a vital commodity and found that it contained something less than expected. In today's environment of just-in-time war fighting, we won't have the luxury of doing our jobs correctly the second time around (Kalleres, 1993, p. 23).

A third reason asset visibility is critical concerns recent "real-world" logistical experiences. While the logistic successes of Operation Desert Storm have been widely heralded, the logistic challenges have also been widely analyzed, so they can be avoided in future operations. For example, many sources have reported that a large percentage (as high as 77%, by some accounts) of the 35,000 containers shipped to Southwest Asia had to be opened at the port to find out what was in them and whom they belonged to (Bonney, 1994, p. 54). This is clearly an inefficient--and dangerous--way to deploy and prepare for combat. Many similar illustrations have been offered as examples of the logistic challenges of Desert Storm, and most have a common thread: the challenge could have been avoided (or at least minimized) if leaders and logisticians alike had some way of knowing the location and status of cargo while it was being transported. Without accurate, timely logistics information, commanders cannot effectively prepare for battle. The inefficiencies that result from having to guess where an item is or when it will arrive could, at a minimum, cause lives to be lost and money wasted; in the worst case, the planning failures could cause execution failures, and a battle or war could be lost. As a writer commented in Jane's Defence Weekly, logistics is truly "the achilles heel of any army." (Foss, 1992, p. 19) Protecting that achilles heel is the goal of Army leaders who are advancing the case for total asset visibility, in-transit visibility, and the supporting systems and technologies.

5. Strategic Logistics Initiatives

Transforming the current logistics system into the continuum of battlespace logistics is clearly a complex task. Throughout the Army, scores of initiatives and programs that are contributing to that transformation are underway. The Army Strategic Logistics Plan includes a listing of those logistics initiatives considered most central to the transformation; together, these initiatives comprise a comprehensive plan to transition to the logistics system of tomorrow. Four criteria are used to determine whether a current project or action is included as an ASLP initiative. To be included, an item must meet one of the following criteria: action directed from higher headquarters; action resulting from changes to Army doctrine, policy, tactics, or force structure; high-priority action required to shape Army logistics in the future; or action involving significant cost or cost avoidance. (ODCSLOG, 1995, p. 4-2) An extract of the ASLP initiatives list is included in the Appendix. A more thorough discussion of automatic identification technology initiatives and the roles AIT can play in transforming Army logistics is presented in Chapter IV.

IV. AIT IN SUPPORT OF TOMORROW'S ARMY

A. COLLECTIVE VALUE OF AIT

Several of the automatic identification technologies discussed in Chapter II have the potential to play important roles for the Army of the future. For example, the Department of Defense recently ordered a two-year evaluation of a smart "soldier readiness card," an identification card containing a computer chip; this card will be used to hold personal information needed for deployment, such as a soldier's financial, medical, and personnel files (ID Card, 1996, p. 1). DoD also announced in 1995 that it would purchase a $70 million RF-tag-based "logistics management system" from Savi Technology. (Gross, 1995, p. 149) It is important to note, however, that no single automatic ID technology can be a panacea for all logistics challenges; it would not be any more appropriate for the Army to base its logistics strategy on a single automatic ID technology than it would be to base its combat strategy on a single weapon system or a single type of combat unit. Different technologies are appropriate for different circumstances. For example, while one would not want to attach a $200 RF tag to every 20-cent bearing the Army purchases, one *could* afford to attach a bar code label to each one, even if the label were only going to be scanned one time. The key is to integrate the appropriate technologies into an overlapping, complementary hierarchy (Topp, 1996).

Of the AIT discussed, it appears that RF tags may have the most *central* logistics role, for two reasons. First, RF tags have the potential to interface with other AIT at various points in the logistics pipeline. For example, data from bar-coded items being placed in a container can be scanned and recorded on the RF tag on the outside of the container; later, when the tag is interrogated, it will transmit information not just about itself, but also about the cargo inside the container. Second, RF tags have certain strengths that make them preferable to other AIT in some of the most challenging logistical situations. For example, the fact that RF tags have no line-of-sight requirement makes them an ideal choice to use to collect information from several hundred containers stored in rows and stacks in a staging area. Bar codes, laser cards, and smart cards--all powerful technologies--would be of little use in the situation described.

For these and other reasons, the Department of Defense has identified radio frequency tag systems as an essential component of future logistics. In fact, the Defense Intransit Visibility Plan prepared by USTRANSCOM, the DoD central transportation manager, states:

> Use of electronic tagging media to mark the contents of containerized and palletized shipments is vital to achieving ITV, particularly in theaters where adequate communications capacity for logistics information exchanges cannot be ensured (USTRANSCOM, 1995, p. 1-9).

In 1994, the Department of Defense selected Savi Technology as its sole source for RF tag systems (Savi (b), 1995). This chapter will look at the capabilities of Savi tags and their potential to work in conjunction with other AIT. The importance of AIT integration with other technologies and systems--such as existing Standard Army Management Information

Systems (STAMIS)--will also be discussed. Then recent experiences with RF tags will be considered. Finally, possibilities for the future will be discussed.

B. SAVI RF TAG SYSTEM

The general characteristics and components of radio frequency tag systems were discussed in Chapter II. The basic components of a Savi tag system, as with other systems, are: the RF tags themselves, interrogators, and system software. Savi systems also offer the possibility of range extension through devices called "RF links." More information concerning each component is provided below:

1. Savi RF Tags

There are two types of Savi tags: the TyTag and the SealTag. The TyTag (production of which was discontinued in 1995) is intended for indoor use and has only 128 or 256 bytes (characters) of standard memory. The SealTag is intended for all-weather use and is available with either 8K (8,000) or 128K bytes of extended memory, in addition to 256 bytes of standard memory. (Savi (a), 1995, p. 26) DoD has decided to purchase SealTags (Donnelly, 1996), so information presented here will focus on that tag type.

The SealTag (Figure 6) is a small, battery-powered transceiver, designed especially for transportation and logistics applications (Savi (a), 1995, p. 39). The large memory capacity is designed for applications requiring storage of manifests or other documents. The tag has a serial port, which allows it to interface with external devices, such as fuel gauges or other sensors. The SealTag can accept and store data from such devices, then later transmit that data when interrogated (Savi (b), 1995). The SealTag has a real-time clock, so it can date stamp data or events that occur. It also has an audible beeper that can be heard about 200 feet away (Savi (c), 1995). The beeper can be turned on remotely and used to help locate a particular tag.

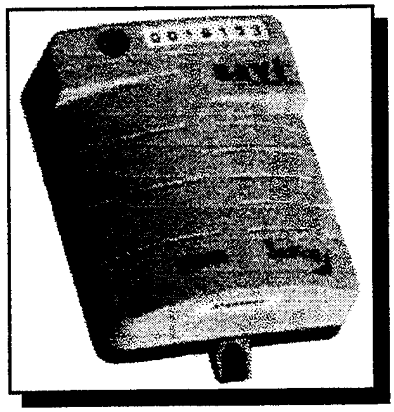

Figure 6 Savi SealTag
(Savi, 1996)

The SealTag is powered by a 6-volt lithium battery, which is replaceable through an access door in the tag. The tag automatically reports low battery strength during data collections. According to Savi, each battery should last four years with two collections per day. (Savi (c), 1995) To ensure the battery lasts as long as possible, Savi has incorporated a "sleep" feature into the tag: unless a tag is communicating with an interrogator, it is "asleep" or dormant. While asleep, the tag consumes very little energy. The only activity within the tag is that the internal receiver turns on 2 milliseconds out of every 2.5 seconds to listen for a signal from an interrogator. (Both fixed and hand held interrogators incorporate a "wake up" feature that transmits an RF or infrared signal to the tag to wake it up.) If the receiver detects this "wake up call," the tag will wake up and communicate with the interrogator; if it does not receive a signal, the receiver will turn off and the tag will remain asleep. Because of the receiver's 2.5 second on-off cycle, Savi interrogators transmit wake up calls that are at least 5 seconds long, to ensure the tag receives the signal. (Alonso, 1996)

When transmitting data, SealTags use spread spectrum technology, which--under FCC regulations--permits them to be operated without a license. Spread spectrum transmission is also regarded as being more reliable in certain applications, because data is transmitted consecutively on multiple frequencies: even if interference blocks part of the data on a particular frequency, the receiver can collect the total data package by collecting whatever data is available from each frequency in the particular range being used, as shown in Figure 7. Under FCC rules, spread spectrum output power is limited to a maximum of 1 watt, which effectively limits the range of systems using this transmission method. (Andel, 1992, p. 35) The SealTag range is 300 feet, unobstructed (Savi (a), 1995, p. 40).

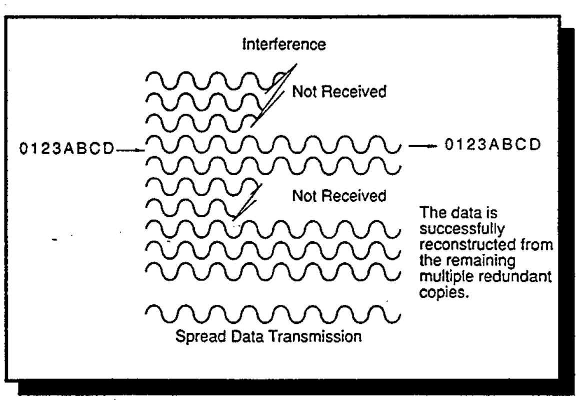

Figure 7 RF Spread Spectrum Technology (Andel, 1992, p. 32)

Each Savi tag has two types of identification. The principal means of identification is the tag ID number, a unique seven-digit number built into the tag memory during manufacture, which cannot be changed. The tag ID is the only identification actually read during "collection" (reading of tags in a particular area); however, since a factory-selected number may not be as meaningful to the user as one he selects himself, SealTags allow a secondary identification means. This secondary means, termed "SysLabel," allows the user to give tags a "name" that relates to a specific application. (Savi (d), 1995, p. 3-2) For example, a tag's SysLabel might be given a value of "28trans" (a specific military unit) or "tools," (a specific commodity). When a tag collection is performed, tag ID numbers are collected, cross-referenced with a SysLabel file stored in the system computer and hand held interrogators, and the user-selected "names" are displayed on the computer or hand held interrogator being used.

2. Savi Interrogator

Savi radio frequency readers, or *interrogators* (Figure 8), are the principal means of communicating with Savi SealTags. Savi interrogators use a proprietary "Batch Collection" algorithm to communicate with all tags within their range. This protocol allows an interrogator to query and receive information from up to 3,000 tags nearly simultaneously. (Kourupes, 1996) Interrogators have a range of about 300 feet in a typical unobstructed installation. (Savi (a), 1995, p. 45)

Interrogators communicate with the system computer either through radio frequency transmission, using an RF link module (below), or by "hardwire," using RS-232 or RS-485 connections. If RS-485 connections are used, multiple interrogators can be networked with a computer. Individual interrogators set up in a network can also be set on "repeater" mode, thus significantly extending the area covered by the network. (Savi (a), 1995, p. 45)

Figure 8 Savi Interrogator
(Savi, 1996)

Interrogators have rugged, weatherproof housings and are available with hardware suitable for either "ready-to-mount" or "field-deployable" installations; the former is for fixed or semi-permanent installation, the latter for temporary installation (Savi (a), 1995, p. 47). The ready-to-mount configuration is shown in Figure 9. For ease of discussion, both configuration types are sometimes referred to collectively as "fixed interrogators" to differentiate them from the hand held interrogator, which is described below. Fixed interrogators can be powered by 110/220 volts AC, 6-15 volts DC, or by a solar power module.

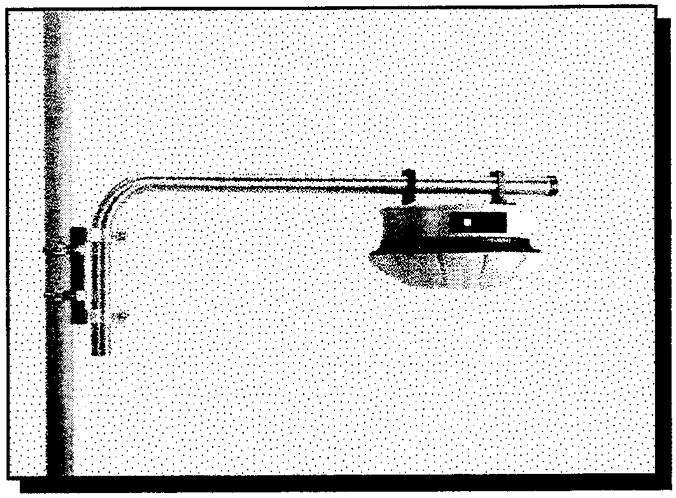

Figure 9 Ready-to-Mount Interrogator
(Savi, 1996)

3. Savi Hand Held Interrogator

The hand held interrogator (Figure 10) is a portable interrogator "designed for use where it is impractical or undesirable to install a fixed interrogator." (Savi (d), 1995, p. 1-1) Using a hand held interrogator (HHI), a user can communicate with tags in a particular area, then store tag data temporarily in the HHI for later transfer to a host computer. (Savi (d), 1995, p. 1-1)

The HHI can communicate with tags via radio frequency or through a serial cable. The radio frequency method is most commonly used; however, using a serial cable (connected to a port in the HHI and to a particular tag) facilitates the transfer of a large amount of data in a short time, thus conserving battery power. (Savi (d), 1995, p. 1-2) The HHI is powered by a rechargeable, 6-volt nickel-cadmium battery, which lasts twelve hours under typical operation (Savi (a), 1995, p. 54).

Figure 10
Savi Hand Held
Interrogator (Savi,
1996)

4. Savi RF Link Module

The RF link module (Figure 11) provides wireless communication between fixed interrogators--both ready-to-mount and field deployable--and a host computer. The module has an effective range of at least 5,000 feet (unobstructed) and can also serve as a standalone repeater, providing even greater range for communications with Savi tags. A second proprietary protocol, Adaptive Routing, allows multiple RF link modules to "automatically establish communications with each other to provide automatic configuration and recovery when modules are removed or relocated." (Savi (a), 1995, p. 51).

RF modules are connected to interrogators or the system computer through an RS-485 cable connection. The modules have the same weatherproof housing as interrogators.

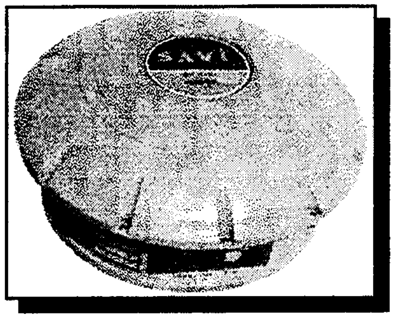

Figure 11 Savi RF Link Module (Savi, 1996)

They can be powered by 110 or 220 volts AC, 6-15 volts DC, or a solar power module. (Savi (a), 1995, p. 51)

5. Savi System Software

Savi system software controls the interrogators, either individually or in a network. Savi offers a variety of software systems. TagOS, for example, is a graphical-based database that operates in an MS-Windows environment. Another package, Savi Interrogator Network Controller (SINC), provides "the low-level control needed to communicate with and operate the fixed interrogators and Savi tags." SINC versions are available for both MS-DOS and MS-Windows applications. (Savi (e), 1994, p. 2)

C. INTERFACING WITH OTHER AIT

As of this writing, bar codes are the only AIT with which Savi SealTags can directly interface. The Savi hand held interrogator is available with a bar code scanner (Figure 12) that reads Code 39 bar codes (the DoD standard format). One valuable application possible with this combination of AIT is the capability of creating a shipping manifest by scanning the shipment data can immediately be transferred to the RF tag on the outside of the container, either by RF transmission or by wire linking the HHI and tag. The data can also be transferred to a system computer using the same means (Savi (a), 1995, p. 55)

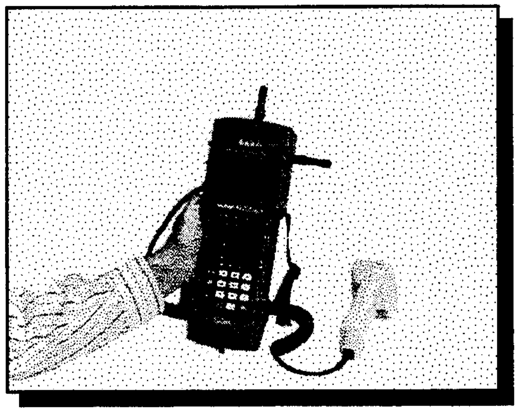

Figure 12 Hand Held Interrogator with Bar Code Scanner (Savi, 1996)

Other AIT interfaces are certainly possible, though not yet developed. Since all AIT discussed in this thesis ultimately involve various means of transferring data to a computer, any one of the technologies could theoretically interact with any other. That is, assuming the data in question can be stored in a mutually-compatible format, it could be recorded or "read into" a computer using one AIT, then processed by the computer so it can be used by another AIT. Savi, for example, is developing a method to interface optical/laser cards with Savi tags. The interface system would essentially consist of a card reader that would read the data from the card, and a hardware/software package that would allow that data to be transferred to a SealTag (Alonso, 1996). The card-tag transfer may end up involving an existing piece of Savi hardware: the "docking station" shown in Figure 13. The docking station is designed for the direct, rapid transfer of data from a personal computer (PC) to a SealTag. (Savi (a), 1995, p. 43) The data the PC sends to the tag may have been manually input or may have come from a database or other automated source. In the case of an RF tag-laser card interface, the PC would receive data from a card reader, then download it to an RF tag. As in the bar code example above, this capability could be especially valuable at the beginning of the shipping process, when a large amount of shipping data must be entered on the RF tag that will accompany a shipment.

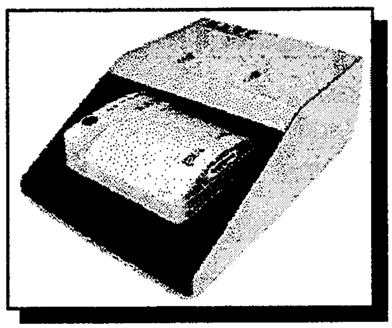

Figure 13 Docking Station
(Savi, 1996)

New Cumberland Army Depot in Pennsylvania is currently using a prototype of a system that may develop into this tag-card interface. At New Cumberland, a docking station is being used jointly with other hardware to "burn" (record data onto) laser cards and RF tags simultaneously. The laser cards--called "AMS cards"--are an integral part of the Defense Logistic Agency's Automated Manifest System (AMS), which represents an effort to reduce or eliminate the *paper* documentation that accompanies DoD shipments and to increase the accuracy of the documentation (in this case, electronic data on the laser card) that does accompany each shipment. (Yeager, 1996) By writing information on the laser card and RF tag simultaneously, DLA is using a single automated data source to feed into both AMS and the RF- tag-based in-transit visibility system. However, an appropriate goal is for AMS cards and RF tag systems to eventually be able to interface at other locations and times in the logistics pipeline.

D. INTEGRATION WITH OTHER TECHNOLOGIES AND SYSTEMS

1. Need For Continuous Information

While RF tags and the other automatic ID technologies are powerful in certain applications, they cannot perform all the myriad requirements of battlespace logistics by themselves. Just as a single AIT cannot satisfy all the complex logistics needs of the Army, a single technology *group*--AIT--also cannot satisfy those needs by itself. One of the central requirements of battlespace logistics, for example, is that Army commanders, planners, and materiel managers have continuous visibility of materiel as it moves through the logistics pipeline. However, RF tag systems cannot provide that sort of continuous positional information; the information from such systems is only "nodal" in nature--based on discrete nodes at which interrogators have been mounted (Topp, 1996). Such systems only notify users that a particular tag passed a particular system node at a certain time. That is, they do not reveal where a particular tag (or load or vehicle) is *now*.

One way to achieve the continuous location knowledge that battlespace logistics and ITV require is through satellite-based tracking systems. Several companies market hardware and software products that use satellite-based communications to track the location of vehicles, trains, and so on. Several major trucking firms have already fully integrated these systems into their operations. For example, Schneider, the truckload transportation firm mentioned earlier, has outfitted its 9,000 trucks with satellite-based communications systems that enable dispatchers to do everything from re-routing drivers around bad weather to monitoring their speed. In fact, Schneider has integrated information technology into its operations so completely that it has been described as "an information system masquerading as a trucking line." (Solomon, 1994, p. 54). Confirming this thought, Schneider's CEO commented, "People get the mistaken impression that our business is running trucks." (Solomon, 1994, p. 54) In his comment, the firm's head is alluding to the fact that the company exists to manage logistics by managing *information*--not simply to load cargo in trucks and move it from place to place.

Realizing the Army must also manage logistics by managing information, the Army Office of the Deputy Chief of Staff for Logistics (ODCSLOG)--along with USAREUR--recently purchased 120 Mobile Communications Terminals (MCT) from QUALCOMM. The terminals are part of QUALCOMM's OmniTRACS system, which it refers to as a "two-way satellite-based mobile communications system." (QUALCOMM, 1995, p.1) At this writing, USAREUR is using OmniTRACS to track trucks and trains delivering materiel to U.S. forces in Bosnia. (This application is discussed in more detail below.) The system appears to be providing better positional information than Army logistics managers have had before in operations of this scope; however, the OmniTRACS system currently cannot interface with the RF identification system that is being used simultaneously (Yeager, 1996).

2. Need to Avoid Parallel Processes

Another essential requirement of any technology supporting battlespace logistics is that it be able to interface with (if it does not replace) other essential Army information systems. If a particular emerging technology cannot interface with the existing, relied-upon systems, both new and old systems may have to be run as separate processes, resulting in significant inefficiencies, such as having to enter data multiple times or in multiple formats or having to maintain redundant records. In the case of RF tags, it is essential that they interface with the Standard Army Management Information Systems (STAMIS), which are widely-used as sources of logistics data by Army logisticians at all levels. Examples of the such systems are the Army's automated supply system, SARS (Standard Army Retail Supply system) and its automated repair part management system, ULLS (Unit Level Logistics System).

SARS and ULLS are fundamental to the supply and logistics operations of many Army units. Like many other Army information systems, these STAMIS require data to be input in highly-specific, standardized formats, and they produce standardized reports. Among other functions, both SARS and ULLS involve monitoring the status of items a unit has ordered but not received--items that are "due in." There are clear benefits to be gained from integrating such systems with RF identification and the other technologies that support in-transit visibility: instead of relying on systems that simply inform one that an outstanding requisition is still valid or that a part is due in, a supply sergeant would be able to determine actually *where* that much-needed part is and approximately when it would arrive at his location. However, currently RF tags cannot interface with these or any other Army STAMIS (Topp, 1996).

The principal reason the Army's emerging RF tag systems cannot interface with its existing STAMIS derives from the manner in which the STAMIS were originally programed. When the STAMIS were developed ten to fifteen years ago, each routine within the programs was designed to receive data from a punch-card source, a keyboard, or a file transfer; the architectures were not left "open" to accommodate future communication and information technologies. (Topp, 1996) As a result, the Army's emerging RF-tag-based ITV system cannot gain information from other Army (or DoD) systems that also possess essential logistics data, nor can the RF tag data be shared with another system to help create efficiencies. Sometimes this inability to integrate is very pronounced. For example, consider the Worldwide Port System (WPS), another system that would offer synergy opportunities if it were integrated with RF identification systems. One of the central (and voluminous) categories of data maintained by WPS is "containers in port." However, even though an RF tag system could easily gather as much data as is needed on all containers passing through a port, there is currently no way to pass that data to WPS. Furthermore, because of the way WPS was originally created, the containers in port data must be input into WPS *manually* (Topp, 1996).

E. CURRENT AND RECENT ARMY APPLICATIONS

As RF tagging technology has developed, it has been tested or fielded by the military in various forms. A look at some examples will help shape an understanding of future capabilities of this technology.

1. Early Testing and Use

a. Desert Storm Retrograde

In 1992, RF tags manufactured by the Amtech Corporation were used in Southwest Asia to track retrograde shipments--including 320,000 short tons of ammunition--moving from various locations in Saudi Arabia to the port of Damman. The Amtech tags were mounted on the 703d Transportation Battalion's fleet of over 2,000 trucks, then interrogated by readers in a number of locations, ranging from fixed readers mounted on port gates to solar-powered units in the middle of the desert. The port readers transmitted the "read" data to the base station by RF; the desert readers transmitted data through land line to a modem, then to the base station. (Fletcher, 1996)

The usefulness of the system was particularly apparent at the port, as the delicate process of loading multiple types of ammunition, hazardous cargo, and other classes of supply on vessels was undertaken. As a vessel was being loaded and a particular type of cargo (e.g., specific fuse type) was needed for a particular spot, the RF tags on each truck allowed staging area supervisors to identify a specific truck with that cargo type and call it forward. (Fletcher, 1996)

While this early use of RF tags was considered effective, several significant work-arounds had to be made integral parts of the system. For example, load manifest data had to be manually entered into the system database; it was not available from any automated source. Soldiers from the transportation battalion painstakingly typed in the contents of every trailer before each convoy departed--including critical details such as ammunition lots and fuse types. Also, the system could not directly use transportation movement data from the Department of the Army Movement Management System (DAMMS); instead, DAMMS information was manually downloaded as an ASCII file, then uploaded into the RF system's database. In fact, a large measure of the operation's success may be attributable to the fact that a single battalion commander was responsible for the entire process--from movement control to line haul transportation--and was simply able to direct actions (such as manually entering the details of every load) that shippers might have objected to. (Fletcher, 1996)

b. European Retrograde

In 1993, tags manufactured by Savi Technology were tested during the movement of retrograde ammunition from Germany to the United States. Ammunition containers being moved from several storage sites were tagged, so that specific hazardous cargo information--such as ammunition type, lot, and quantity--could be read from outside the container. Having this information readily available eased the process of hazardous cargo load planning and movement, as in the example above. (Langen, 1995, p. 2)

c. *Somalia*

Later, the first field use of Savi tag systems occurred during support of peace-keeping operations in Somalia. About 200 air pallets destined for Somalia were tagged and tracked; later, when military equipment was returned to the U.S., about 100 containers were tagged and tracked. A total of six fixed interrogators were mounted in various staging areas, and hand-held interrogators were also used. (Langen, 1995, p. 3) The operation proved to be a good test, because of the short notice deployment, and because of the need to maintain a long supply line moving supplies and personnel "in and out of a place where infrastructure ranged from inadequate to nonexistent." (Bonney, 1994, p. 55) Logisticians involved began to realize that the enhanced knowledge about in-transit materiel enabled them to modify the flow of supplies in transit, rerouting or redeploying material when needed. This operational test also showed the tags to be reliable, since they "cross[ed] the Atlantic many times, and last[ed] for about 50,000 reads before needing replacement batteries." (Langen, 1995, p. 3)

2. JLOTS 1993

Further real-world testing of RF tag systems took place during the 1993 Joint Logistics Over The Shore (JLOTS) exercise. In JLOTS, an annual exercise, the military services work together to test their ability to support ground forces from the sea by moving supplies over an unimproved beach and further inland. In the 1993 JLOTS, a portion of the exercise cargo was actual Army retrograde cargo from Europe. Before the exercise, 130 vehicles, 75 ammunition containers, and 220 general cargo containers were identified and tagged while still in Europe. The cargo was then transported by ship across the Atlantic

Ocean. Once it reached the North Carolina coast, it was transferred to lighters and barges and moved over the shore at Camp Lejeune's Onslow Beach. Interrogators strategically placed along the beach collected tag information, with a few of the most difficult or remote landing sites being covered by "mobile" interrogators mounted on vehicles. (The vehicles were stationary while the interrogators were being used.) As materiel departed the beach, interrogators along the route reported movement progress. (Savi (c), 1995)

Monitoring stations were established at the 1st Corps Support Command (COSCOM) and 7th Transportation Group headquarters. The various interrogator networks provided managers both visibility of the ongoing operation and data with which they could affect the operation by controlling and directing resources. This "advance notice" provided the corps Materiel Management Center (MMC) "a view of cargo inbound to the corps not previously available." (Savi (c), 1995) In actual operations, this same information would facilitate materiel managers' ability to divert and reconsign cargo as the tactical situation changes. During the exercise, the advance notice, plus the ability to read container contents remotely, allowed logistics personnel to organize storage areas by commodity and destination and to marshal cargo vehicles accordingly. Further, the Movement Control Center (MCC) was able to use the same AIT data to prepare movement plans and schedule resources to execute those plans. Inland, at the operation's staging area, the effectiveness of the RF tag system was tested in a different way: while teams of cargo checkers worked to record receipt data using manual methods, "an unmanned interrogator captured full documentation information in a fraction of the time." (Savi (c), 1995)

Overall, this demonstration of RF tag technology can be considered successful; however, it is important to remember that this use of RF tags was essentially the "introduction of a non-integrated technology" (Topp, 1996) into JLOTS. That is, while the RF identification system provided valuable management information and operated over significant distances, it was still a stand-alone system. It was not integrated with any STAMIS, and in some cases, exercise participants still had to perform parallel or redundant processes, such as routine Worldwide Port System transactions. However, the scope and success of this RF tag application did "demonstrate the art of the possible." (Topp, 1996)

3. Haiti

In 1995, XVIII Airborne Corps support activities were linked to the developing DoD in-transit visibility system to facilitate the support they would be providing to units deploying for Operation Uphold Democracy. Supply activities at New Cumberland, Pennsylvania and Fort Bragg, North Carolina were linked by modem with a central supply database at Letterkenny Depot, Pennsylvania. Interrogators were set up at embarkation points--Jacksonville, Florida, and Charleston Air Force Base--and in Port au Prince, Haiti. All cargo bound for Haiti from Fort Bragg or New Cumberland was tagged. (Langen, 1995, p. 3) In fact, Uphold Democracy was apparently the first actual operation in which the operation's commander-in-chief said, "Don't send anything to this theater without an RF tag." (Topp, 1996)

Data from the RF tag system--particularly data about cargo inbound to the theater--was used across the corps for various functions. While the data could not be shared with

DAMMS, SARS, or other STAMIS, the data was still valuable "off-line." A senior officer who headed CASCOM's Logistics Automation Directorate during the operation commented that the value of RF tags in this operation was that logisticians and commanders "could see the pipeline from source to consumption." (Topp, 1996) Another source summarized the benefits of this particular RF tag application as follows:

> Soldiers in Haiti were able to pull up data on shipments from the moment the manifest was written onto the tag, and monitor the progress of the air or sea shipment on its way to the Caribbean. Unnecessary reorders were drastically reduced, because logisticians could determine the location of incoming material in minutes. Inventory was minimized, and the ability to divert and reassign material was enhanced. (Langen, 1995, p. 3)

4. USAREUR Distribution Demonstration

In the second quarter of fiscal year 1996, the Army launched an even larger RF tag application. In support of the United States Army, Europe (USAREUR) battlefield distribution demonstration, an RF identification system was implemented that allowed monitoring of cargo from a CONUS depot to USAREUR units. Containers being shipped from the Defense Distribution Depot Susquehanna Pennsylvania (DDSP) to Europe were tagged. Interrogators were installed at two CONUS ports of embarkation (Dover and Newark), the USAREUR port of debarkation (Ramstein Air Base), and multiple sites in USAREUR. The USAREUR sites are listed in Figure 14. (LIA (b), 1996)

- 1st Armored Division, Bad Kreuznach
- European Redistribution Facility (ERF), Nahbollenbach
- 1st Armored Division Class IX, Baumholder
- United States Army Medical Materiel Center (USAMMC), Pirmasens
- Hub and Spoke Distribution System (HSDS) Hub, Kaiserslautern
- Ramstein Air Force Base
- Friedrichsfeld
- 596th Maintenance, Darmstadt
- 3d Infantry Division, Kitzingen
- FedEx Terminal, Frankfurt

Figure 14 USAREUR Interrogator Sites (LIA, 1996)

Concurrent with this demonstration, DoD officials mandated a standard format for recording data on RF tags. Termed "TAV" (for Total Asset Visibility), the format includes data grouped in three sections: license plate data, commodity data, and TCMD (Transportation Control and Movement Document) data. A sample is shown in Figure 15. The first section is termed "license plate" data, because it contains basic identifying data that uniquely identifies the overall container with a particular consignee. The second section, TAV commodity records, lists the details about each commodity or "line item" included in the container. The data in this section is configured as a database, so interrogators that

License Plate

S ITM0000 TCMD0003
CONTAINER 12345
LEAD TCN
WK4FW0012V002KK2
POE-JF6 POD-1N4
CONSIGNEE W23QLL
TP3 HAZMAT E
FREE TEXT COMMENTS
01.01

TAV Commodity Records

```
NOMENCL       DOCUMENT           LIN     NSN                RIC UI  QTY CC     INT-TCN                 MISC1                MISC2
HELICOPTER    ,WK4F4250120003  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,SERVICE            ,ARMY
TANK          ,WK4F4250120105  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,CONTAINER NUM,40125
F14           ,WK4F4250120154  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,COMM CLASS         ,CLASS-5
HMMV          ,WK4F4250120092  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,LEAD TCN           ,WK4FW40012V
JEEP          ,WK4F4250120 003 ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,OPERATION          ,DESERT SHIELD
MOTORCYCLE    ,WK4F4250120105  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,HAZMAT CODE        ,C
DODGE VAN     ,WK4F4250120154  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,CONSIGNEE          ,W17BSH
PLS           ,WK4F4250120392  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,POE                ,KF2
MINESWEEPER   ,WK4F4250120103  ,000139,8010009588147     ,123,EA,00005,A,WK4FW40012V002J.IK2,POD                ,2B0
```

TCMD Records

```
TE260018USAA2041614   JF61N4 YCWK4FW40012V0012V002KK2W25G1F 2233S01122J10650001388521280
TE460018WK4FW44164    JF61N4VF1W80D1F20090027AXXW80D1F         233S01122J10650001388521280
TE660018USAA2041614   JF61N4VF1W80D1F20090027AXXW80D1F 25G1F 2233S01122J10650001388521280
TE760018USAA2041614   JF61N4 YCWK4FW40012V0012V002KK2W 25G1F 2233S01122J10650001388521280
TE960018X0905941614   JF81N4 YCWK4FW40012V0012V002KK2W 25G1F 2233S01122J10650001388521280
```

Figure 15 DoD TAV Format (Savi, 1996) remotely communicate with the tag can also actually search the tag memory by any of the data fields, such as nomenclature, document number, or national stock number. The third section, TCMD records, includes the many data elements that are normally on the TCMD that must accompany all cargo transported within the Army. This data includes, for example, the origin and destination unit "addresses"--known officially as Department of Defense Activity Address Codes (DODAAC)--and the Transportation Control Number (TCN) for each shipment within the container.

An overview of the USAREUR baseline system is provided in Figure 16. In this system, interrogators at the various sites read only license plate data from the tags. The license plate data is then passed to a "fusion center" at the Volpe National Transportation Center in the United States. In the fusion center, the tag data is integrated with supply data from the Army Logistics Information File (LIF). (The LIF includes such data as document numbers, order status, shipping dates, and so on.) The merged data is available to users through a system called Army Total Asset Visibility (ATAV). Using their existing computer, users can contact the ATAV host computer via modem and retrieve information about status and location of materiel. The user interfaces with ATAV through a series of screens designed to be more user-friendly than certain Army information systems--such as LIF--have been in the past. (Yeager, 1996)

When the baseline system was established, USAREUR was able to monitor cargo that originated at DDSP, flowed through Dover, Newark, Ramstein, and Frankfurt, and arrived at 1st Armored Division direct support units. (LIA, 1996)

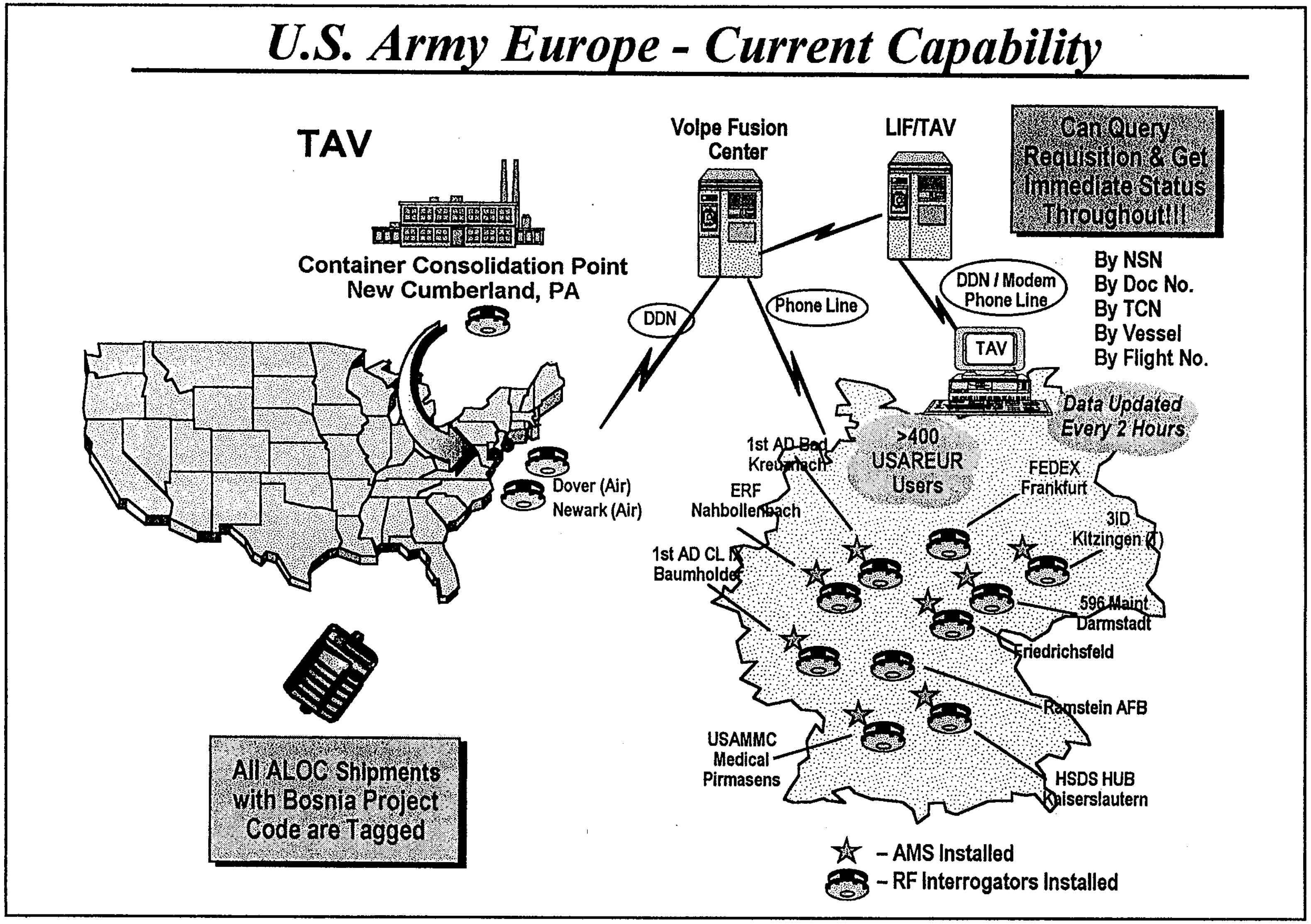

Figure 16 Current USAREUR Automatic Identification Network (LIA (b), 1996)

5. Bosnia

a. RF Tag System

As Operation Joint Endeavor (OJE) began, the Army significantly expanded USAREUR's RF identification capability to enhance support provided for U.S. forces deploying to Bosnia. For OJE deployment and support, additional interrogators were installed at railheads in central Europe, Hungary, and Croatia. Initially, as units were deploying, tags were "burned" by mobile "burn teams" at unit locations in Germany; however, as of this writing, tags are only being burned at New Cumberland Army Depot and the Kaiserslautern hub and spoke terminal. All containers being shipped from USAREUR locations to Bosnia are tagged. Also, all high priority Air Line-of-Communications (ALOC) cargo shipped from DDSP to Bosnia is tagged. At the Susquehanna depot, Defense Logistics Agency (DLA) representatives are tagging the air pallets; in USAREUR, soldiers, civilians, and LIA contractors are tagging the containers bound for Bosnia. (SLA, 1996)

b. QUALCOMM System

As discussed before, RF interrogator information, while valuable, cannot give logisticians "the whole picture," because it does not provide the continuous, positional information that is necessary to be able to monitor and control the materiel flowing into and throughout the theater. Consequently, Army planners have selected the satellite-based OmniTRACS tracking system to help monitor truck convoys and rail movements. Termed "Defense Transportation Tracking System" (DTTS), the system being used in Europe employs QUALCOMM satellite-based transceivers to monitor movements. The mobile communications terminals are installed in the last truck in a truck convoy or last rail car on a train. Then every hour (for convoys) or two hours (for rail movements), MCTs pass location data via satellite to a QUALCOMM database in Paris. (SLA, 1996)

c. ***Shortcomings***

(1) Empty Tags. While the logistics support of OJE represents a bold step forward in several areas--a step closer to leveraging technology to bring Army support forces closer to the reality of "battlespace logistics," for example--the execution does still have a few shortcomings. First, cargo is arriving in Bosnia that either has no RF tag or has one that is "empty," that has had no information recorded on it (Topp, 1996). This situation reflects two logistics challenges that have faced many logisticians:

- It is difficult to identify and control *every* point from which cargo can enter the logistics system. That is, certain valid shipments are probably originating at locations other than New Cumberland and the USAREUR designated tagging sites, and they are not being "captured" and tagged as they enter the pipeline.
- No amount of technology can eliminate oversights or errors or compensate for poor training. Since many of the problem shipments are *tagged*--but not properly tagged--some may be caused by oversights, errors, or lack of training on the part of logisticians or customers.

The short term solution to this tag problem has been to attach a tag on the spot or to type all the data into a hand held interrogator, then use the interrogator to download the data onto the tag. Both steps are clearly time consuming. Further, having to perform either step so far forward in the pipeline is the antithesis of what should occur in a well-functioning automatic identification system: in such a system, one should be able to *automatically* receive identifying data, without having to manually process the cargo.

The principal elements of the long term solution are already implied above. Army logisticians and other leaders must work to fashion a logistics pipeline that is more "closed" in the sense of knowing each possible beginning and ending of the pipeline. They must also work to ensure that everyone involved with the pipeline understands the significance of their roles, however large or small, and the potential impact on the overall system if they do not perform those roles--such as "burning" tags--correctly.

(2) No Interrogators Forward. A second shortfall concerns availability of essential hardware in forward locations: in some cases, hand held interrogators have not been issued to logisticians at forward processing locations, such as trailer transfer points (Fletcher, 1996). This situation is clearly the direct opposite of what needs to occur for an RF-tag-based automatic identification system to function throughout the logistics channel: everyone who is involved in receiving, processing, or shipping cargo should have ready access to an interrogator, either fixed or hand held. If those individuals cannot electronically "read" what is in the container, pallet, or vehicle, then the automatic ID system fails at that point. The solution is self-evident: logisticians must work to identify each place or person that will be involved in reading or processing data and ensure that location or that person has the hardware and software required to do so.

(3) No Real-Time Integration of Tag and QUALCOMM Data. As discussed in the technology integration section earlier, the real-time linking of the satellite-

based position notification and the RF-tag-based automatic identification systems could bring us closer to the intent of in-transit- and total asset visibility. With these technologies functioning together, logisticians would know both where in-transit materiel is and what the details of its status are. Currently, however, the QUALCOMM communications and the RF tag data collection are functioning as completely independent systems. While the QUALCOMM communication occurs every one to two hours and is passed via satellite to a QUALCOMM server in Paris, the RF data collection occurs each time a tag passes an interrogator, with the information being passed to an ITV server in Friedrichsfeld, Germany. (Yeager, 1996) While logisticians and contractors are working to integrate the systems, as of this writing, they have not yet achieved that goal.

F. AIT'S ROLE IN FUTURE LOGISTICS

From the discussion thus far, it is clear that automatic ID technologies--particularly RF tags--can play a central role in future logistics. In the operations and exercises reviewed above, it appears that each successive application has added capabilities or otherwise expanded the realm of "the possible." As automatic ID technologies develop further and as the Army and its support forces move further into the Information Age, there are many additional areas into which AIT can be introduced to support battlespace logistics. Besides the improvements mentioned above (such as interfacing multiple technologies and integrating major systems), there are a variety of possible applications. Three such applications are discussed below:

1. Automatic Manifesting

RF identification technology offers the potential for implementing a system that creates electronic manifests that are automatically incremented or decremented as items are added or removed from a shipment. Such a system would have tremendous value for the entire Army logistics pipeline. A system being developed for the Marine Corps illustrates the potential of automatic manifesting. The Marine Corps and the Naval Facilities Engineering Service Center (NFESC) are developing an RF tag system for one of the most demanding military operations: support of a Marine Corps OMFTS (Operational Maneuver From The Sea) operation. (An OMFTS operation is one in which Marine combat elements are logistically supported from the sea, and in which a large logistics support area is probably not available ashore (Torres, 1994, p. 36).) Adapting RF technology for amphibious operations is demanding, because

> Amphibious logistics applications require complete geographic latitude, environmental independence, and visibility of assets in the warehouse, ship, truck, and even the container. (Torres, 1994, p. 36)

To support the OMFTS application, the NFESC is supervising the development of three RF tags:

a. Satellite/location tag. This tag communicates with a satellite, providing identification and location data, independent of local communications systems.

b. Package tag. This inexpensive, disposable tag is placed on each item to be loaded in a container.

c. Database/manifest tag. This tag is placed on each container and incorporates both a database and a reader for package tags. (Torres, 1994, p. 36)

In this fully-integrated system, a container's database/manifest tag will create an electronic "manifest" by reading the package tag on each item loaded in the container. As items are later removed from the container, the database/manifest tag will decrement the records stored in its memory, so the tag always has an accurate record of what remains in the container.

Army operations of the future may well be as challenging as an OMFTS operation and conducted in the same austere environment. The logistics required to support Force XXI operations will likely make demands on logisticians similar to the demands listed above for amphibious operations. Automatic manifesting could offer increased efficiency and accuracy at every step of the battlespace logistics pipeline: from the moment a container is loaded at a contractor's factory or a CONUS depot, till it reaches a maneuver unit in contact with the enemy, anyone who needed to know the container's current contents with precision could get that information. While currently-available tag systems can provide container content information, an automatic manifesting system adds two key elements. First, the incorporation of the package tag offers the potential for increased accuracy by *decreasing* the likelihood of manifesting errors, such as forgetting to annotate the removal of an item from a container. Second, the incorporation of the location tag offers the potential for improved positional knowledge about critical materiel, as opposed to the nodal-type of information that logisticians currently rely on.

2. Maintenance Returns

The Force XXI Army will be a rapid-deployment force, projecting power from mostly CONUS bases to a wide variety of potential theaters. The Army of the early twenty-first century will probably maintain little materiel stock in the United States and little or no stock in forward locations, such as central Europe; consequently, it will have to rely on well-functioning battlespace logistics to get the materiel it needs to fight or perform other assigned missions. (Akins, 1996) This fact, combined with the likelihood of continued declining budgets, makes it essential that Army logisticians maximize their knowledge about all possible sources of supply. One source that could prove valuable if managed properly is *maintenance returns*, items that have been repaired and are being returned to units or the supply system for further use. "Maintenance returns" could refer to items as diverse as tank and aircraft engines that have been overhauled or tents and stoves that have been repaired.

RF tags are an ideal way to track any high-value, much needed component as it is retrograded for repair by direct support units, depots, or civilian firms, then later returned to the supply system for reuse. By monitoring this additional supply source, logisticians and commanders can make more informed decisions about which units should be given priority for certain items. For example, a unit's combat effectiveness may be hampered by the fact that it is waiting for a replacement tank engine that is due-in from the supply system in ten days. If, however, the battlespace and battle command logisticians are monitoring tank engines that are being repaired, they may discover that a rebuilt engine is due-in from a repair facility in only two days. Data such as this could allow for supply cross-leveling or even modification of operational plans. (Akins, 1996) It is possible that a commander or logistician could make life-saving or battle-winning decisions based on information such as this--information that can be made available by a well-thought-out, integrated RF identification system.

3. Theater-Level Stock Management

Finally, it is possible that the automatic manifesting concept could be applied on a theater level. That is, during an operation, an automatic identification-based system could be used to monitor all items (such as containers, vehicles, and major assemblies) that enter or leave the theater. The resulting data would be used to manage the theater "inventory" and possibly even to generate reorders of certain items. As an illustration of this concept, consider how Kmart and other major retailers use bar code systems. Besides simply scanning the bar code on each item to expedite cash register transactions, many firms also use the same bar code scan to debit their inventory records. In some systems, when the inventory has been debited down to the reorder point for a particular item, the integrated point-of-sale/inventory system automatically generates an order for that item. (Akins, 1996)

While theater-level knowledge of inventory levels could prove valuable for commanders and logisticians, with a well-operating battlespace logistics system it would not necessarily be desirable to automatically order items. As we have seen, the essence of battlespace logistics is to operate a continuous "factory to foxhole" pipeline so that stocks are *not* needed, so automatically ordering items (which could lead to the accumulation of stocks) may not be appropriate. Further, Army forces of the future will have to be highly mobile, and accumulating stocks would conflict directly with that goal. However, having accurate, real-time information about theater stocks would greatly facilitate battle-winning decisions such as those discussed under maintenance returns. And for critical consumable items--such as food, water, fuel, and ammunition--it may in fact be appropriate to combine automatic notification of stock levels with known consumption rates, and automatically order those commodities.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

1. Powerful Tools

Radio Frequency tags clearly are powerful tools--tools that offer many possibilities for Army support applications. RF tags and the other automatic ID technologies cannot individually resolve all logistics challenges associated with operating on tomorrow's battlefields; however, when coupled with other emerging technologies and existing systems, RF tags can provide Army logisticians and commanders information and capabilities that they have not previously had and that it appears they will need to help soldiers survive on those future battlefields.

The Army faces strong pressures today, both financially, due to reduced budgets, and structurally, due to Congressionally-mandated downsizing. Related pressures have been brought to bear by the Army's new mission orientation (rapid-deployment instead of forward-deployed) and the smaller amount of personnel and equipment with which to accomplish its mission. As discussed earlier, these circumstances are also *reasons* that commanders need a system that tells them where their limited assets are and that helps ensure the assets are moved to the appropriate place on time. Radio Frequency tags are not the complete answer, but they can play a key role in such a system. RF tags can help ensure smooth logistic support of an amphibious assault or help track critical equipment moving to a theater of operations. To a limited degree, an RF tag by itself can provide on-the-scene data to a commander not able to access a remote database. And, when linked to a local or centralized database, RF tags play a critical role in giving commanders complete in-transit visibility, so they can ensure they get the right equipment where they need it and when they need it.

On the other hand, RF tags are *not* the best automatic ID technology for every application. First, they cost more than other technologies. The cost (and other issues) make them non-disposable and thus not appropriate for certain applications, such as marking disposable items or large numbers of small, inexpensive items. Certain types of RF tags have other limitations, such as sensitivity to metal and to radio interference, but those do not seem to be significant issues with respect to the DoD-selected Savi tags.

2. Supports Strategic Logistics Vision

Chapter III identified the Army's strategic logistics vision and nine logistics objectives that support that vision. The information provided by a well-planned RF tag system working jointly with other technologies can play a central role in achieving the vision of a "seamless logistics system capable of providing world-class logistics support." (LIA (a), 1995, p. 5) Automatic identification technologies appear to be an *essential* component of any larger system that will ultimately be able to accomplish the demanding strategic objectives established for Army logisticians. The objective, for example, to "establish visibility of stocks in storage and in-transit" (LIA (a), 1995, p. 5) probably cannot be accomplished on an Army-wide scale without automatic ID; on the contrary, automatic ID technologies will probably be *required* in order to have visibility of materiel throughout the length and breadth of the Force XXI pipeline.

3. Supports Battlespace Logistics

When properly integrated with other Army systems (such as the various STAMIS) and DoD systems (such as the Worldwide Port System), it appears that RF tags and the other AIT will be able to facilitate effective logistics at all critical steps along the continuum of battlespace logistics. From national provider to battle command logistician, and ultimately to the unit in contact with the enemy or engaged in an operation other than war, all elements of the pipeline will benefit from enhanced knowledge of where essential materiel is and when it will arrive at the location at which it is needed.

B. RECOMMENDATIONS

1. Further Research

Several areas related to the topic of this thesis merit further research. One area that should be explored extensively is the integration of automatic identification technologies with other systems and technologies. In particular, a study of potential methods for achieving connectivity between an RF tag-based automatic identification system and Army STAMIS would be appropriate. A study of potential methods for integrating an RF tag system with a satellite-based communications system would also be appropriate. A third, related area of research would be looking at methods of integrating RF tag systems with Global Positioning System (GPS) technology.

Another area that should be explored is possible methods and applications for interfacing radio frequency tags with other AIT. As discussed, Savi Technology already markets a hand held interrogator/bar code reader combination, and one CONUS depot has a method for "burning" laser cards and Savi SealTags simultaneously; however, research should be done on ways in which various AIT can interface at any location in the logistics pipeline.

2. Other Actions

Army leaders should invest manpower and money in achieving connectivity between automatic identification systems and the critical STAMIS, such as SARS and ULLS. Developing a system that can truly interface at key points would eliminate the need for running dual processes simultaneously. Army leaders should also commit resources to establishing real-time connectivity between radio frequency tag systems and satellite-based communications and tracking systems.

Army logisticians should work to make the logistics pipeline more "closed," so that every item that flows through it can be tagged or otherwise marked and monitored. Logisticians and planners should work to ensure that appropriate automatic identification hardware and software are available at every point in the pipeline in which a logistician or a customer needs to interact with the materiel being shipped or received; the goal, after all, of automatic ID technology is for users to be able to quickly gain accurate knowledge about an item without opening or otherwise manipulating it.

APPENDIX. STRATEGIC LOGISTICS INITIATIVES

This appendix contains an abbreviated version of the complete initiatives list, which is contained in Appendix C of the Army Strategic Logistics Plan (dated 28 February 1995). For this abbreviated list, items were selected that give an idea of the number of Army-level initiatives that relate to the subject of this thesis.

ASLP initiatives are organized in four groups termed "corporate categories," which are indicated in the list below. Tabbed indents in the list indicate subordinate initiatives.

CAT I: Strategic Mobility

- Containerization Policy
- Force Structure Initiatives
- Advanced Technology
  - Digitization
  - In-Transit Visibility
  - Deployment Analysis Tools
- Logistics Support Element

CAT 2: Distribution and Sustainment

- Joint Computer-Aided Acquisition and Logistic Support
- Total Distribution Program
- Asset Visibility Policy
- Interactive Technical Manuals
- Total Army Inventory Management

CAT 3: Develop Battlespace Logistics Automation Architecture

- Create Central Certified Data Base
  - Logistics Integrated Data Base
  - Worldwide Ammo Reporting System
- Develop/Field National Level Provider System Configuration
- Design/Field Single Logistics System with Embedded Functional Applications
  - Standard Army Retail Supply System
  - Standard Property Book System

Standard Army Ammo System
Standard Army Maintenance System
Unit Level Logistics System
Develop Enabling Technologies
Total Asset Visibility Database
Intransit Visibility
RF Tag (AIT)
Laser Cards
Global Transportation Network
Soldier's Readiness Card
Knowledge Based Logistics Planning Shell
LOGMARS
MITLA-AIT
Total Distribution Advanced Technology Demonstration

CAT 4: Reorganize to Battlespace Logistics Structure

Design and Implement Force XXI
Total Asset Visibility
Develop Battlefield Distribution System
RF Tag (AIT)

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